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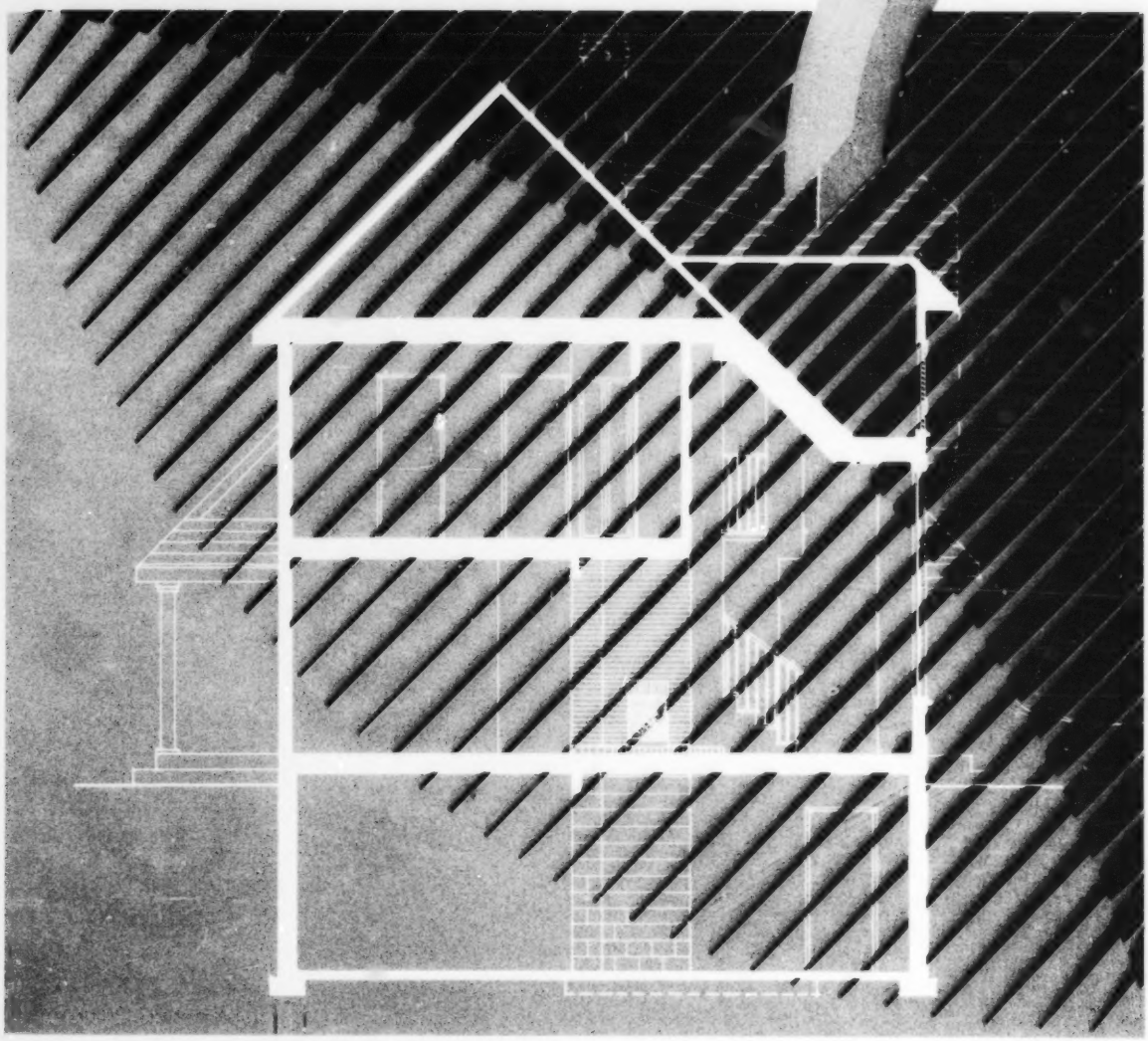
PASSIVE SOLAR HOUSE DESIGNS for Canada



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PASSIVE SOLAR HOUSE DESIGNS for Canada

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Introduction

The oil embargo of the 1970s caused people to look at the potential of solar energy and other conservation and renewable energy sources to reduce dependence on fossil fuels. Since then, Canada has become a leader in energy-efficient housing and examples of our energy-efficient housing technology have been exhibited around the world.

A major component of an energy-efficient house is passive solar energy; typically 20% - 25% of the annual space-heating energy needs of an energy-efficient house are met by the sun. Until recently, the building community has been reluctant to increase the passive solar contribution much above this level. Refinements in analytical techniques and improvements in window technology, together with advancements in mechanical equipment, now make it possible to double the amount of passive solar energy an energy-efficient house can use, while maintaining occupant comfort. This means that new energy-efficient homes may have greater emphasis placed on the passive solar components, more solar amenities such as glazed sunspaces for the occupant, and lower purchased energy consumption.

The Advantages of Passive Solar Design

The concept of energy-efficient passive solar design has great appeal for the homebuyer. Builders have found that large windows, skylights, and solariums are good selling features. Buyers also put a high priority on low energy costs. Other components of solar design, such as good distribution of daylight, spacious open stairwells and decorative masonry feature walls, are found to be selling features in many conventional new homes.

Designers who may have found passive solar design restrictive or ineffective in the past will discover that the new highly insulative glazings permit a greater range of effective window orientations; and current analysis tools are accurate and, for the most part, simple to use.

In addition to attractive architectural features, passive solar designs offer other advantages. The passive solar home should provide a greater level of thermal comfort than conventional homes — more even temperatures, no drafts, and comfortable humidity levels. Indoor air quality should be superior because the energy-efficient passive solar home has a controlled ventilation system to provide a continuous supply of fresh air. And the energy performance should be as good as or better than any other energy-efficient house of the same size and similar location.

How to Use This Book

Although much has been written about energy-efficient construction, there is little up-to-date information about passive solar design for Canada. This book is a first step in redressing the balance.

The book is intended for designers, builders and owner-builders. Part 1 introduces the principles of passive solar design. While not a how-to manual, it provides design guidelines and refers to the detailed analytical tools required for design.

Part 2 contains 24 simple, direct-gain energy-efficient passive solar house designs. Tables containing energy-efficient construction details for four different climatic regions are also included.

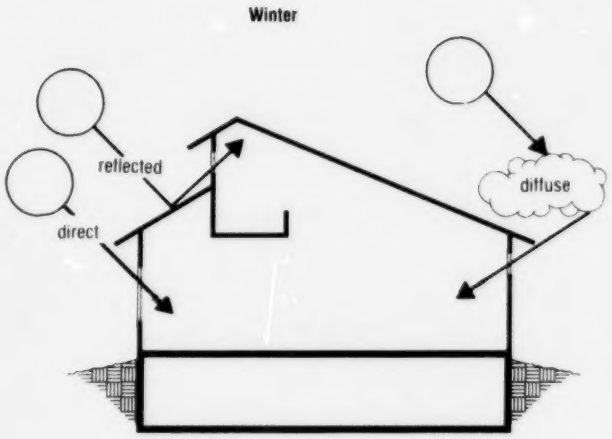
1. The Principles

Passive solar homes provide great opportunities for sunny windows, greenhouses and solariums, but a good solar house is considerably more sophisticated, and effective, than a house that simply has lots of south-facing glass. An energy-efficient passive solar home provides a comfortable, attractive, even luxurious, environment; it makes good use of the sun's energy for heating and lighting, and reduces the need for purchased fuel. On the other hand, incorrectly designed passive solar houses can be uncomfortable because of glare or extreme temperature swings and may have increased fuel bills. It is important, therefore to understand the principles of passive solar design when designing or choosing a solar home.

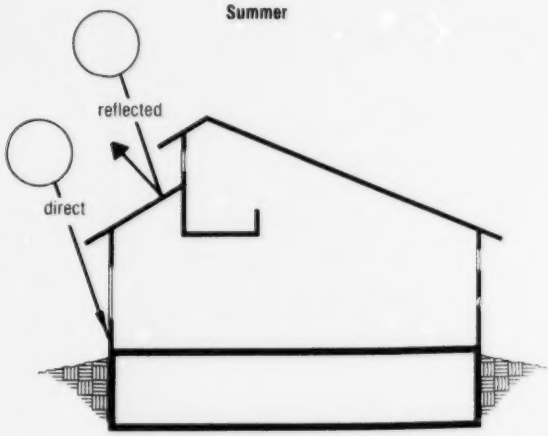
Solar Radiation

Anyone who has sat by a sunny south-facing window on a cold winter's day has felt the effects of passive solar heating. The sun's energy passes through the glass in the form of short-wave light. When the light strikes an opaque object it is absorbed and converted to heat. Because the winter sun is low in the sky, the solar radiation strikes vertical window glass at close to 90 degrees and the sunlight penetrates deep into the room. During the summer months, when extra heat is undesirable, very little direct sunlight can penetrate the house through a vertical south window because the sun is high in the sky. Thus solar energy is available to a house in the winter months when it is needed but does not overheat the house during the summer (figure 1).

Figure 1 Solar Radiation



In winter, solar radiation enters the house mainly by direct rays but to a significant degree by reflected rays and by diffuse radiation scattered in the atmosphere and striking all surfaces.



In summer, the radiation is overhead most of the day with little penetration through vertical windows, which are easily shaded with overhangs.

Direct sunlight generally provides the greatest proportion of the usable heat but **diffuse radiation** from the sky on an overcast day and **reflected** light from snow on the ground around the house also supply useful energy.

Solar Contribution

Most houses are partially heated by the sun. The amount of solar heat provided during a heating season is called the **solar contribution** (or solar fraction). The solar contribution is expressed as a percentage of the **total space heating load** of the building during the same period. The bottom line, the homeowner's fuel bill, is the difference between the total space heating load (less internal gains from occupants, lights and appliances) and the solar contribution.

The solar contribution may be used to assess a house at the design stage. As figure 2 indicates, it is theoretically possible to achieve solar contributions approaching 100%, but to do so with current technology is impractical. An achievable goal is the utilization of about one quarter of the available energy; this is because about half of the available solar energy is lost through reflection and poor transmission through the glass, and half of the remaining energy is available when it is not needed and cannot be stored. The annual solar contribution for a passive solar house is typically in the range of 25 - 40%. The limiting factors are the climate, the window thermal performance and the ability of the house to store solar energy. These percentages are relative and a house whose total annual heat losses are high will have higher heating bills than a house with more modest losses, even if a higher proportion of the heat is provided by the sun. The overall energy performance of a design is ultimately more important than the solar contribution.

Figure 2 South Window Size Required to Receive 40 GJ of Solar Energy During the Heating Season

Location	Area (m^2)
Winnipeg	14.1
Swift Current	14.6
Edmonton	14.9
Fredericton	16.0
Ottawa	16.1
Halifax	17.4
Montreal	17.4
Charlottetown	17.4
Toronto	18.9
St. John's	22.0
Vancouver	23.2

Most of the house designs in this book have a heating load of 40 GJ (gigajoules) of energy per year. The chart indicates the size of solar aperture that receives 40 GJ in various locations. In practice, only a fraction of the incident radiation can be used because of transmission through the glass, reflectance from inside, and the limits of storage capacity.

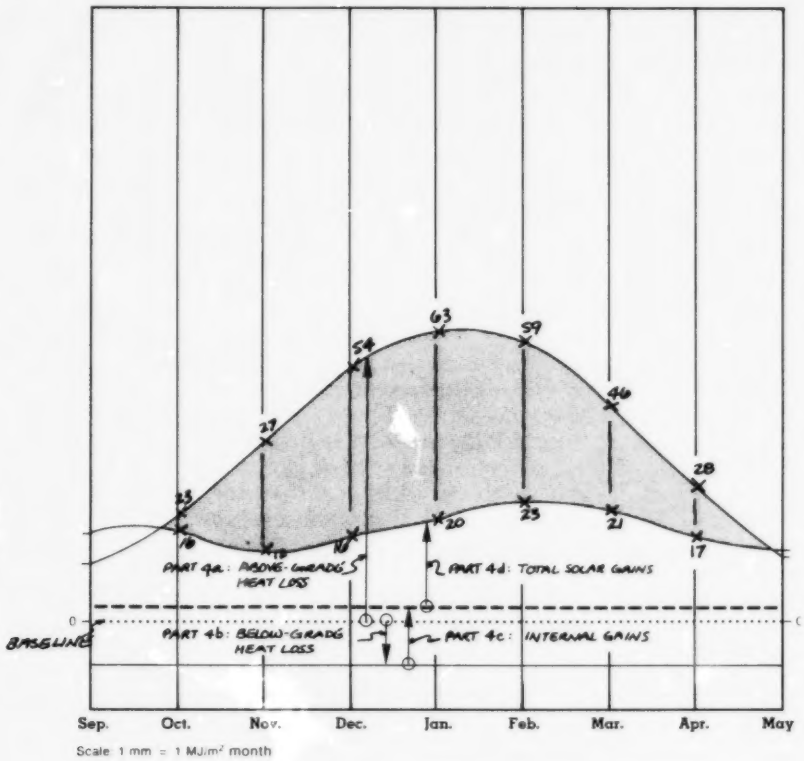
Elements of Passive Solar Utilization

A passive solar system has four major components: solar collection, heat distribution, storage, and energy conservation.

1. **Solar Collection:** The objective is to select the glazing orientation, area and type that gives good energy savings. Although a south-facing window admits energy to the house, it also allows heat to escape; conventional windows are poor insulators. Passive solar designs must employ glazings and window orientations that ensure a net gain to the house — the solar gains must exceed the heat losses through the window over the course of a heating season. If there is adequate heat circulation and thermal storage to accommodate the solar gains, a window that provides a net heat gain to the building performs better than a well-insulated wall.

Beyond a certain point, the addition of more south glass will not improve the performance of a passive solar home. There is a limit to the amount of solar heat a building can use and if that limit is exceeded the occupants may find the house too warm during the day and too cold at night. Moreover, too much south-facing glass can mean higher fuel bills. Apart from providing heat, however windows also provide natural light, ventilation, architectural character and opportunities for growing plants. If more window area is needed than is necessary for the collection of solar heat, measures must be taken to ensure thermal comfort and performance.

Figure 3 Annual Space Heat Energy Graph



Scale: 1 mm = 1 MJ/m² month

Summary			
Total heat losses minus internal gains	62	340	MJ/m²
Useful solar gain	59 × 64	135	MJ/m²
Annual energy consumption	65	37.7	GJ/yr
Annual energy cost	66	419	$

Note: All calculations in this graph refer to designs in CMHC's publication *Grapheat*. The graph is represented here simply to illustrate *Grapheat's* method.

2. **Heat Distribution:** Only a part of the heat admitted to a building can be used immediately; the rest must be circulated throughout the house or stored for later use. The passive solar house is designed for good heat distribution and natural air circulation; fans or blowers are often part of the design.

3. **Storage:** The nature of solar radiation is such that thermal storage, whether intentional or not, is an integral part of every passive solar house. The thermal storage provided by conventional building materials — plasterboard, concrete block, plywood, and so on — may be increased if necessary. Heavy building materials such as masonry and tile or double layers of plasterboard may be used in rooms receiving direct sunlight to store heat. For example, Designs 17 and 18 use concrete block party walls for thermal storage; Design 9 uses a double layer of drywall and a brick fireplace wall. Glazed mass walls (Trombe walls) can be used on the south walls of buildings and solar-heated air circulated through hollow concrete floor slabs or rock storage bins. Water-to-air heat pumps provide highly-efficient remote water storage that can heat the house or the domestic hot water supply.

4. **Energy Conservation:** A passive solar system will not function effectively unless the house is designed to contain the collected heat. Conservation levels such as those required to meet the R-2000 standard should be employed. This standard requires the use of high levels of insulation, airtight construction techniques, controlled ventilation and an efficient heating system. Passive solar designs use somewhat less insulation than a non-solar design to meet a given energy budget. For comfort, safety and long-term energy savings, however, the house should

incorporate a complete package of conservation features. The designs in this book should be built to the National Building Code 1983 Measures for Energy Conservation or better.

Design Integration

A passive solar design usually employs several measures in combination to achieve optimum performance. For example, Design 1 would perform best with ceramic tile floors in the south-facing entry and a double layer of plasterboard in the south zone of the house for thermal storage. The double-height entry permits air to circulate naturally but the natural circulation is assisted by a high air-return to the furnace, located at the top of the stairwell.

Design Tools

Much of the art of passive solar design involves finding the right balance between glazing type, size and location, thermal storage, air circulation and the efficiency of the building envelope. The guidelines presented in the following chapters should be sufficient for preliminary design purposes. Once preliminary drawings are prepared, a detailed analysis should be done to fine-tune the design.The designs in this book have been through this engineering process and may be directly translated into working drawings containing good, energy-efficient detailing; it is recommended, however, that analysis be done on the working drawings to ensure good performance with the chosen glazing and energy-efficiency measures. The following thermal analysis tools are recommended:

Manual method using GRAPHEAT, a simple method for quickly estimating passive solar performance. Using a series of graphs and tables such as those shown in figure 3, the technique allows the designer to calculate the total heat loss for a house, the total solar contribution, and the expected maximum indoor temperature swing due to solar heat gain. GRAPHEAT was used to calculate the performance of the designs in this book. A companion technique — GRAPHSHADE — allows the designer to determine shading effects. The GRAPHEAT method is outlined in two CMHC publications: GRAPHEAT and GRAPHSHADE. (See Further Readings.)

Computer software — HOT-2000, the easiest to use and quickest microcomputer program. It is also the official analysis tool of the R-2000 program and a design must meet the R-2000 Energy Budget, determined by HOT-2000 analysis, as the first step in registration as an R-2000 house. This program does not yet predict temperature swings.

Computer software — ENER-PASS, a powerful, detailed and sophisticated analysis tool which gives hour by hour simulations in addition to seasonal totals. It is suitable for analyzing complex designs or for checking outputs from other programs, particularly when unusual design strategies are employed.

Other software programs, several U.S. programs on the market can provide thermal analysis for passive solar houses. They include F-Load, SERI RES, and CALPAS 3.

Summary

Passive solar houses are designed to make effective use of the sun's energy and to minimize the use of purchased energy. A careful design and analysis process should be followed that pays special attention to:

1. the selection, sizing and location of windows (solar collectors);
2. the design for distribution of heat throughout the house;
3. the inclusion of thermal storage;
4. integration of the passive solar features and other energy conservation measures with the aid of performance analysis tools.

2. Collecting Solar Heat

Windows and other glazed openings are the solar collectors of a passive solar house. Until recently, houses with lots of glass, even south-facing glass, would generally be less energy-efficient than a well-insulated house with very little glass. Advances in window technology and mechanical system design together with the availability of easy-to-use thermal analysis tools now make it possible to build highly energy-efficient passive solar houses. But, for the house to function properly and be comfortable to live in, the glazing must be carefully considered.

Net Gain and Solar Orientation

Glass admits solar energy to the house, but it is a poor insulator. An insulated wall might have a thermal resistance (RSI) of about 3.5; double glazing with a 12 mm airspace has an RSI value of 0.35, ten times less insulative than the wall. A window must admit more heat than it loses over a heating season to provide a net gain to the house.

Windows do not have to face due south to function effectively as solar collectors, but the greater the deviation from south, the more insulative the window must be to provide a net gain. For example, in the Ottawa region, east or west-facing high-performance triple glazing will provide a very slight net gain whereas double glazing will lose energy. Some glazings now under development will provide a net gain in any direction. Figure 4 shows the seasonal net gains or losses for windows which face in different directions.

The preferred solar orientation is southwards. In addition to the net gains, the following factors should also be considered:

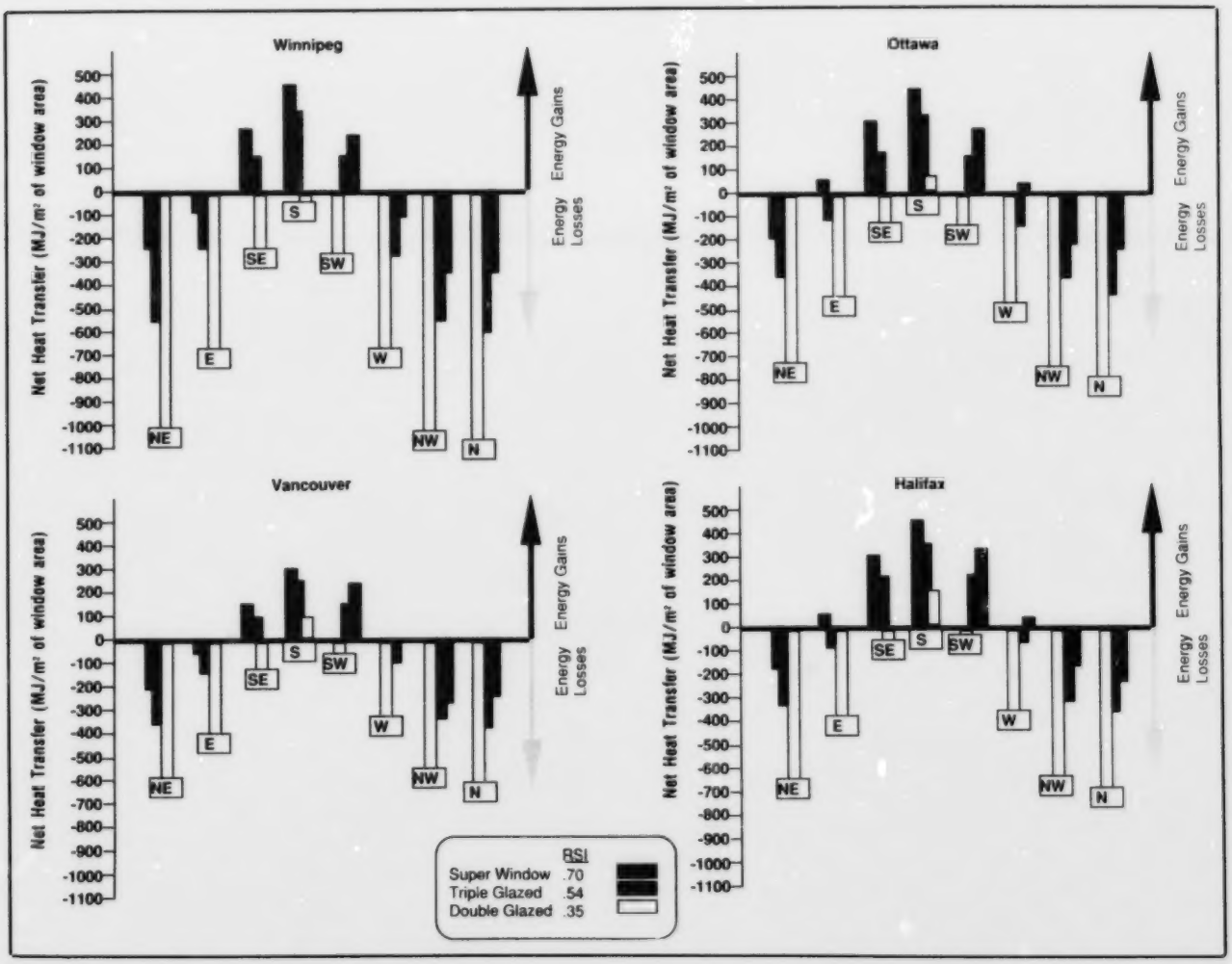
1. It is easy to control excess summer gains through south-facing windows because there is little solar penetration. Additional shading can be provided by awnings or other devices. It is more difficult to shade and therefore control solar gains for easterly or westerly windows.
2. Non-south windows distribute winter gains unevenly during the day. For instance, a west window provides little solar gain in the morning but a lot in the

afternoon — generally an undesirable situation. On the other hand, an east window receives most of its daily solar gains during the morning. Some east windows may be advantageous, since the heating requirement is likely to be greater in the morning, owing to cool outside temperatures and because the house temperature, after night thermostat setback, is cooler in the morning.

Rules of Thumb for Solar Orientation

- **Preferred orientation: the major portion of the window area should face between 15° west of south and 20° east of south.**
- **Acceptable orientation: windows should face within 30° east or west of south.**
- **If highly insulative windows are used, the window orientation becomes less critical and it may be preferable to locate the windows so that all areas of the house receive good daylight, and therefore dir t gains.**
- **The use of north-facing windows should be kept a minimum, regardless of the type of windows used.**

Figure 4 Seasonal Net Gains versus Orientation



Temperature Swing

When sunlight enters the house and strikes a solid object, the object becomes warm. The warm surface in turn warms the air around it. The result is that the sunny part of the house very quickly becomes noticeably warmer than the rest of the house. The heating process continues as long as the sun is shining. Gradually, even without any forced-air circulation, the whole house becomes warmer and the part of the house receiving the sunlight becomes hot.

Rules of Thumb for Temperature Swing

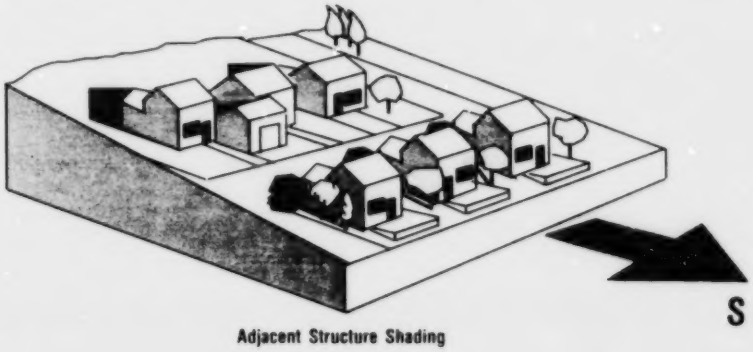
- **In mid-winter, a small temperature swing of up to 6° C is acceptable.** A large temperature swing of 8° C or 10° C is not. As soon as the house begins to be too hot, the occupants open windows to vent the heat. Effective solar gains cease and heat already collected is lost. For analytical purposes, any solar gains which result in a temperature swing of more than about 5° or 6°C are considered to be vented outside. Each design in this book has a calculated maximum temperature swing value.

- **Large expanses of west-facing glass should be avoided.** West and sometimes east-facing windows may cause overheating problems, particularly in summer, spring and fall. This overheating is caused by the low angle of the sun in the western (or eastern) sky. During late afternoon and evening (morning) the sunlight can penetrate deep into the room through west (east) windows and heat the house as effectively as the mid-winter sun at noon. During the marginal months and in summer, little of this heat is needed; the rest must be vented or stored before overheating occurs.

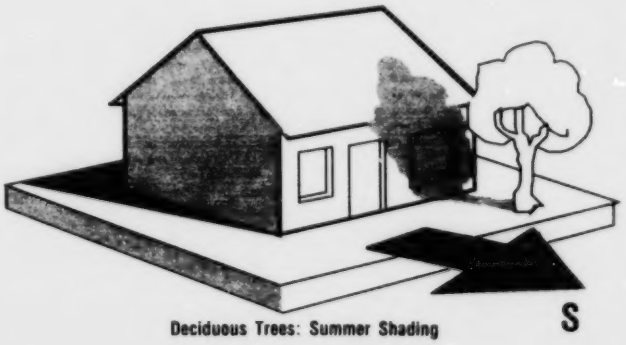
Winter Shading

During the heating season, southern shading is almost always unwanted and should be avoided as far as possible. Unless the building lots are large, east-west streets are preferable for passive solar homes, since buildings and trees on adjacent properties can be a problem in the case of north-south streets. If part of the south elevation will be shaded, the windows should be located as far as possible on the unshaded portion. In some cases it may be possible to rotate the building a few degrees to reduce or eliminate unwanted shading. It is better to have windows that receive some sunlight, even if it is not south light, than south-facing windows that receive little because of shading.

Types of Shading



Adjacent Structure Shading



Deciduous Trees: Summer Shading

Deciduous Trees: Winter Shading

Rule of Thumb for Avoiding Winter Shading

Select a site on the north or south side of an east-west street without southern obstructions. Sun path charts may be used to determine the amount of shading a site will receive at different times of year.

Summer Shading

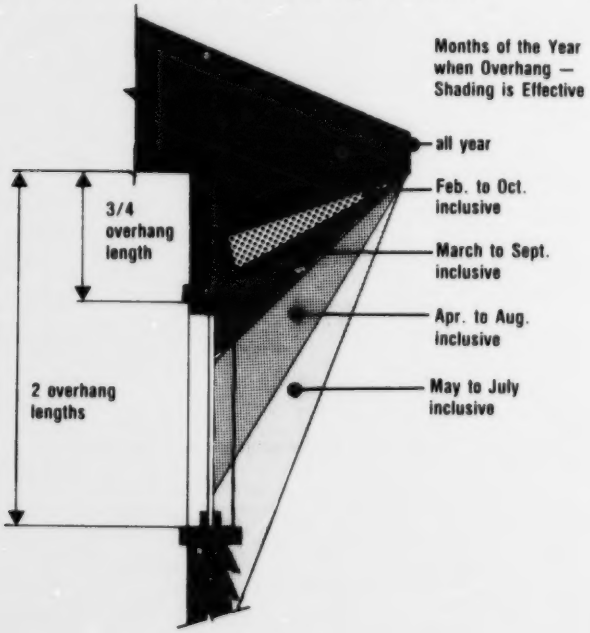
One objective of good passive solar design is to prevent overheating during summer, spring and fall, when there is little requirement for heat. The following methods may be used to reduce the amount of sunlight that enters the house, but fixed shading devices should be used with caution because they block daylight at all times of year.

Awnings. Overhead retractable awnings are a good method of limiting the entry of sunlight through south, southeast and southwest windows. The awning can be folded up against the house or removed when more heat or light is needed.

Overhangs. Architectural elements such as eaves and balconies may be used to provide permanent south window shading. They must be correctly sized so that they do not obstruct the entry of the winter sun, or block too much daylight. Wing walls or trellises may be used to block east and west sunlight. See figure 6.

Blinds and curtains. Blinds and curtains with a white or reflective backing provide a degree of shading for windows of any orientation and have the advantage of being easy to operate from inside. Because they are inside the house, however, and therefore do not prevent the entry of sunlight, conventional blinds and curtains do not function as effectively as exterior devices. Blinds or sunscreens that fit between two layers of window glass work better as shading devices.

Figure 6. Seasonally Varying Shading Effect of Overhangs on South-facing Windows


Months of the Year when Overhang — Shading is Effective
all year
Feb. to Oct. inclusive
March to Sept. inclusive
Apr. to Aug. inclusive
May to July inclusive
3/4 overhang length
2 overhang lengths

Low transmissivity glazing. Mirror glass, bronze glass and tinted glass allow less light to pass through than ordinary glass and have been used for many years on commercial buildings to control overheating. The disadvantage is that the glass also blocks needed winter sun. "Smart " glazings which alter their transmissivity are under development, their use may eliminate the need for other shading devices.

Landscaping. Vegetation is a good way to block or filter sunlight to east and west windows. Deciduous or evergreen trees and tall shrubbery may be planted to block direct morning and evening sun year round. Deciduous trees on the south side of a house also provide summer shading. In the winter a large deciduous tree creates considerable unwanted shade and may reduce the available sunlight by as much as 50%. Ground cover around a house reduces the amount of reflected light and so also has a slight cooling effect.

Direct Gain

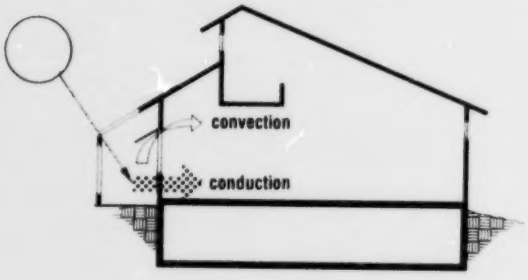
Direct gain is the process by which sunlight heats the room which it enters. Generally, the south rooms of a house are heated by direct gains and the north rooms are heated indirectly by solar-heated air that is circulated from the south to the north side of the house. All the designs in this book use direct gain to the south zone of the house. Direct gain is the simplest and most effective method of solar collection.

Indirect Gain

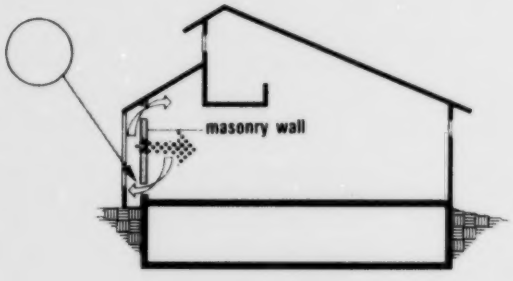
Greenhouses and solariums may be used to collect heat that is then circulated to the living space. The advantage is that greater temperature swings are permissible in an auxiliary space, which does not have to be occupied all the time. By increasing the allowable temperature swings, greater solar utilization is achieved, assuming that there is an efficient method of storing heat and circulating it to the living space. A disadvantage is that the direct gain space is not always at a habitable temperature. If the greenhouse is to contribute to the energy performance of the house, doors and windows connecting it to the house must be closed whenever greenhouse temperatures drop. Auxiliary heaters should not be used to maintain the greenhouse at habitable temperatures, since their use more than offsets any energy savings.

Another indirect gain method which may have advantages in special circumstances is the **Trombe wall** — a south-facing high mass wall of brick, block or poured concrete, surfaced with a dark, selective coating and glazed on the outside. The sun heats the wall which gradually releases the heat to the room behind it. Trombe walls may be practical for some urban situations where, for reasons of privacy or noise, south glass is inappropriate and masonry construction desirable. Trombe walls are expensive to build and their measured performance in Canada has been inferior to direct gain systems. The use of highly insulated glazings and more efficient thermal storage materials may improve their performance in the future.

Figure 7 Indirect Gain

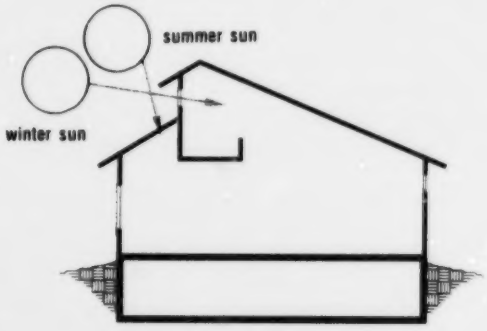


Attached sunspaces or solaria may deliver solar gain to the heated space by natural or forced convection or by conduction through the interposed wall.

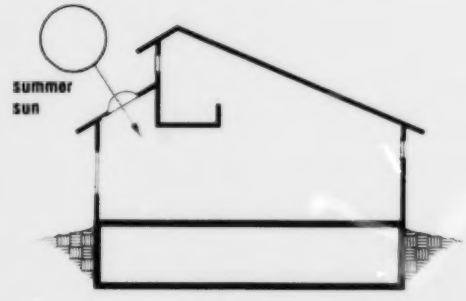


A Trombe wall consisting of glass over an absorbing surface and thermal mass wall delivers heat by natural convection and conduction.

Figure 8 Clerestory Windows versus Skylights



Clerestory windows provide light to north rooms and admit little direct summer sun.



Skylights may result in overheating in the summer.

Rule of Thumb for Selecting Type of Gain

- **Direct gain to the living space is generally the preferred method of collection.**

Aperture Type and Placement

A solar aperture is any glazed opening which admits sunlight. **Vertical glass** is relatively easy to seal and make weathertight. South-facing vertical glass transmits the greatest amount of direct sunlight in the winter, when it is needed, and transmits reflected light from the snow.

Sloping glass or skylights may be architecturally desirable but must be very carefully designed if they are to perform well thermally. Sloped glass loses more heat than vertical glass and admits more sunlight in the summer when the heat is unwanted. The lower the pitch— the closer to horizontal— the worse the performance.

Rules of Thumb for Selecting Type and Placement of Aperture

- **A vertical, south-facing window is the preferred solar aperture.**
- **Sloped glass or skylights should be at least as insulative as the other windows in the house. It may be necessary to use light-reflective glass to reduce solar transmittance.**

The following techniques may be used to admit south light to the north side of the house:

South-facing clerestory windows in the roof may be used to admit south light to the rooms in the north zone of the house. Design 4 uses clerestory windows to illuminate and heat the second floor play area and the main floor dining room.
Cupolas and raised dormers may be used to achieve the same effect.
Solar bays may be used on east and west walls to admit south-east and south-west light respectively. Solar bays are particularly useful for side-yard walls where the view due east or west would be of the neighbouring house.

These techniques are beneficial because solar heat gains are distributed more evenly about the house and natural light is provided to rooms on the north side, without the energy cost associated with north-facing windows. Relocating glass from the north to the south wall saves about 1 GJ /m2/year.

Window Selection

Until recently, window selection was a relatively simple matter. For energy-efficiency the best choices were double-glazed or triple-glazed windows with a 12 mm or greater airspace, and of casement, awning or fixed type. For greater solar transmittance and economy, south-facing windows were sometimes double-glazed and other windows triple-glazed.

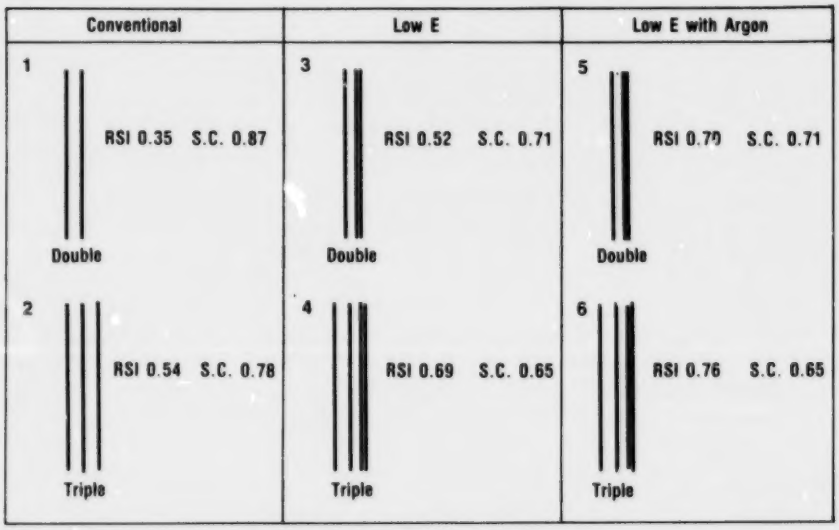
These rules still generally hold true but new products from the window industry are introducing a new era of performance and design flexibility. Some caution is needed in selecting new products, both in ensuring that the design performance analysis is correctly done and that the manufacturer's claims are backed by independent test results.

Glazing Type

For solar performance, glazings are selected for their thermal resistance (RSI value) and solar shading coefficient (S.C.). The shading coefficient is the percentage of energy that can pass through a glazing material. Generally, glazings which have high RSI values have a low S.C., and vice versa. For example, two panes of glass have an RSI of 0.35 and an S.C. of 0.87. Three panes of glass have an RSI of 0.54 and an S.C. of 0.78.

Apart from adding extra layers of glazing, there are several other ways of increasing the RSI value of window glass:
Low-emissivity (low-E) coatings applied to glass or plastic film increase the RSI value of the glazing by reducing radiant heat loss through the glass; a coated double glazing has approximately the same RSI value as an uncoated triple glazing (RSI 1.5 for 12 mm air space).
Inert gas-charged air spaces in a sealed-glass unit increase the RSI value by decreasing convection losses. Argon or krypton gas is used and increases the RSI value of a 12 mm airspace by about 0.06. The effect is greater when the gas is added to a low-E sealed unit.
Improved edge-sealing techniques using non-metallic spacers to reduce heat losses at the edge of sealed glazing units increase the overall performance of the unit. Edge losses can decrease the rated RSI value of the glazing by 10%.

Figure 9. R-Values and Solar Transmission Coefficients



Note: Window spacing is 12 mm.
Edge losses are not included.
S.C., the solar shading coefficient, is the ratio of solar energy transmitted to that for single glazing.

In selecting a glazing type it is important to consider both its RSI and solar transmission coefficient for passive solar performance. Often there is a trade-off since the addition of an extra pane reduces solar gains. However, the net solar gain is always larger; the benefits in reduced glare and UV increased thermal comfort and reduced condensation, as well as larger net solar gains, are sufficiently compelling for homeowners to consider.

Low-E, gas-charged glazings with improved edge seals provide better net performance than standard glazing in most situations and have the added advantage of lower risk of condensation. Manufacturers are now starting to produce glazings with RSI values approaching 1.0. This may not seem very impressive in comparison to a 150 mm fibre glass batt which has an RSI value of 3.5, but it represents a heat savings of two-thirds over conventional double glazing.

Rule of Thumb for Selecting Type of Glazing

- **In general, a passive solar design performs better with high performance glazing than with standard glazing.**
  Performance analysis will help to determine the best glazing options for individual designs. Figure 9 summarizes the properties of various glazings.

Glazing Size

Choosing the right size of solar aperture is critical to the success of any passive solar design. The acceptable area of south facing glass is dependent upon the shading coefficient of the glazing, the presence of any shading, the local climate, the rate of heat loss from the building, the available thermal storage and the rate of air movement within the building.

Rule of Thumb for Selecting Glazing Size:

- **In most parts of Canada, south-facing solar aperture area — that is the actual glass area — should be equal to about 5-8% of the heated floor area.**

The 5-8% rule of thumb provides a useful starting point for a design; it assumes that there is good air circulation within the house to distribute the solar gains and that there is no thermal storage other than that provided by conventional building materials. If there are several rooms on the south side, the glass area should be divided up between the rooms, roughly in proportion to their sizes. The allowable temperature swing governs the glazed area. If the southern glass area exceeds 10%, additional thermal storage must be provided, or the transmissivity of the glass must be decreased. It is important to make sure that the glass area, not the total window area, is calculated; use of the window area will result in insufficient solar gains to the house. Detailed analysis should be used to adjust the final size of the glazed area. See figure 10.

Frame Type

The window frame does not transmit any solar energy, but it may account for more than 25% of the window opening; it should be at least as insulative as the glazed area. Frames that are less insulative than the glass not only lose a lot of heat

but are also likely to be cold enough during the winter for condensation or frost to form on the interior surface. Wood frames provide adequate insulation and can be supplied with exterior coatings of plastic or metal to reduce maintenance. Extruded vinyl and fibreglass frames also work well. Metal frames must be insulated and be "thermally broken" — there should be no metal elements that could act as thermal bridges between inside and outside.

Fixed windows are not as leaky as operable windows and generally have a larger glass area than operable windows of the same size. Operable windows tend to become "drafty" over time as the seals begin to deteriorate. Hinged windows, casement or awning type, have compression seals that generally work better than the seals on sliding windows. Casement windows provide the largest opening for ventilation.

Rules of Thumb for Selecting Frame Type

- **In general, large windows or glass patio doors are preferred to several small windows because they have a greater proportion of glass area to total window area and receive less shading from the frames.**
- **Frames should be at least as insulative as the glass.**
- **Any window not required to open for ventilation purposes should be fixed.**

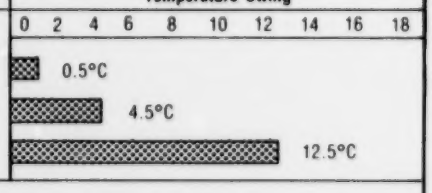
Figure 10. Design Options Using Grapheat (Effects of Window Area)

HOUSE SPECIFICATIONS

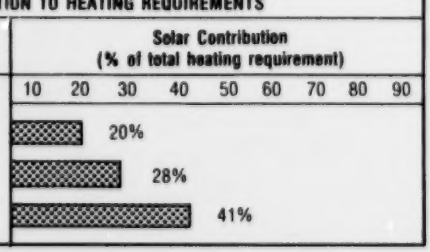
Location: Ottawa
Orientation: Due south
Floor Area: 204 m^2
Glazing: Triple
Insulation: Ceiling RSI 10.5, Wall RSI 6.4
Construction Type: Light, (standard drywall, carpeted floor)
Circulation of Solar Gain: Fan Circulation

SOLAR APERTURE SIZE: Three options — 3%, 6% and 12% of floor area

TEMPERATURE SWING
(on an average January day)



PASSIVE SOLAR CONTRIBUTION TO HEATING REQUIREMENTS

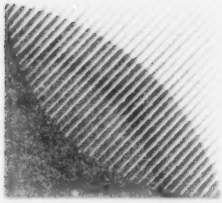


The temperature swing produced by a solar aperture sized at 12% of the floor area is excessive, since a swing of 6°C is generally considered the highest acceptable level. A solar aperture equal to 6% of the floor area makes good use of the sun while avoiding overheating.

Summary

Window sizing, selection and placement are critical to the performance of a passive solar house. The following points should be observed:

1. The simplest and usually the most convenient way to get solar heat into a house is to provide south-facing windows to the living space. Increasing the south window area decreases the purchased energy requirement, especially with RSI 0.5 or better glazing.
2. The majority of the glass in the house should face within 30° east or west of true south. The use of north-facing windows should be kept to a minimum.
3. High performance glazings provide a greater net gain than standard glazings and more design flexibility. The more insulative the glazing, the less critical orientation becomes. Double glazing with a 12 mm airspace is a minimum standard.
4. Overheating can be a major problem in a poorly designed solar home. To prevent overheating, the southern glass area should not exceed 5 — 8% of the total heated floor area, unless additional thermal storage is provided.



3.Distributing Solar Heat

The best way to ensure that solar heat is distributed throughout the house is to design the house so that each room receives sunlight; more information on direct gain is given below. If direct gain is not practical, the heat must be distributed by other means. Normally, this requires the use of both natural and forced air circulation. Circulation of air from the south zone to other parts of the house helps distribute the solar heat throughout the home and enables the entire house mass to act as thermal storage; it also helps to control temperatures on the south side. Without adequate air circulation it is necessary to reduce the solar aperture size to prevent south zone over-heating, which reduces the overall solar contribution. See figure 11.

Daylighting and Direct Gain

Design features such as clerestory windows, cupolas and solar bays can supply southern light into the north zone of the house. In addition, certain interior devices may be used:

The use of light-coloured surfaces, especially on ceilings, helps to distribute light.

Room layouts that connect north and south sides of the house with large openings are a good design feature; glazed **french doors** may be used for sound isolation.

Deadlights are 'windows' in interior walls that allow light from a well-lit space to illuminate a second area. **Glass block** is often used for this purpose. Stairwells, kitchens, laundry areas and showers are all spaces which may be lit and heated in this manner. If ceilings are above standard height, **transom lights** may be used immediately below the ceiling, above eye level. Transom lights are particularly effective when used in conjunction with clerestory windows and light-coloured sloping ceilings. Light from the clerestory is reflected along the ceiling plane and through the transom into the room beyond.

Light shelves and louvres may be used to enhance the effect.

Natural Convection

When air becomes warm it expands and rises, while cooler air flows downwards. This natural convection cycle is a powerful force that can be used to advantage in a passive solar home. Natural convection may be used to circulate solar-heated air about the house and simultaneously to cool the south zone. If natural circulation only is to be used, the rules of thumb that follow should ensure adequate heat distribution.

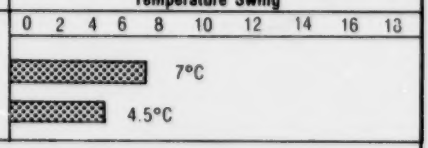
Figure 11 The Effects of Circulating Solar Gain

HOUSE SPECIFICATIONS

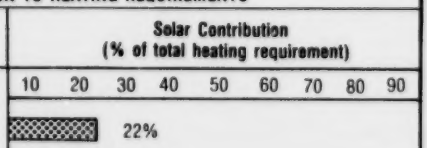
Location: Ottawa
Orientation: Due south
Floor Area: 204 m^2
Glazing: Triple
Insulation: Ceiling RSI 10.5, Wall RSI 6.4
Construction Type: Light, (standard drywall, carpeted floor)
Solar Aperture Size: 6% of floor area

CIRCULATION OF SOLAR GAIN: Two options — no mechanical circulation and fan circulation (300 litres/second when required)

TEMPERATURE SWING
(on an averge January day)



PASSIVE SOLAR CONTRIBUTION TO HEATING REQUIREMENTS



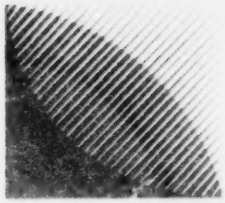
The circulation of solar gains is obviously desirable. The temperature swing produced when there is no mechanical circulation is excessive, and the useful solar contribution drops.

Unless mechanical circulation is provided, the solar aperture size needs to be reduced to maintain temperature swings within acceptable limits. This, however, would reduce the solar contribution even further.

Rules of Thumb for Natural Circulation

- **Compact plans lend themselves to good natural circulation;** little natural circulation will occur between rooms on opposite ends of an elongated ranch-style home.
- **Open plans in which the south rooms connect to the stairwell or to another double-height space work best.** All the detached house designs in this book have this feature.
- **Natural convection can be improved if the design includes uninterrupted flat or sloping ceilings for the air to flow across.** If the need for visual privacy precludes the use of open plan design, partitions may be terminated a few inches below the ceiling.
- **Cross-over registers** may be used in ceilings and floors to permit air to rise from one room to another.

The techniques which give good natural circulation also allow good sound transmission. Sound baffles that cut off direct paths of transmission with sound-absorbing material may be necessary for bedrooms and other areas where sound isolation is important.



Forced-air Circulation

Natural convection may be supplemented by mechanical means. If the house is to have a forced-air heating or air-conditioning system, the same blower and ductwork can be used to move solar-heated air. This solar circulation is normally done by locating the main air return for the system at the top of the house where heated air tends to collect. Design 1 has this type of distribution system. The furnace blower draws the air through the return air duct and distributes it to the supply registers in each room. A forced-air heating system is a convenient means of distributing passive solar gains about a house. There are few additional costs involved since the major components — furnace and ductwork — are required anyway. The ducts deliver air to each room and the amount of air can be adjusted by means of the register dampers. The entire process of solar-gain distribution takes place automatically and, if a heating source such as a wood stove is located in the area of high passive solar gain, heat from the stove will also be circulated.

Natural air circulation in passive solar houses without a forced-air heating system can be assisted by ceiling fans or by blowers:

1. **Ceiling fans** are appropriate for high-gain areas where the cooling effect of moving air is desirable.
2. **Blowers** may be used to move the heated air from the south zone to the rest of the house. A full duct system is not necessary; sometimes it is possible to use a single central ceiling plenum to supply air to both lower and upper non-solar rooms.

Rules of Thumb for Forced Circulation

- **Locate supply registers high in the walls or ceilings to prevent discomfort due to drafts from registers.** Re-circulated air will be at a lower temperature than furnace-heated air, particularly if the distribution ducts are also used to supply fresh ventilation air.
- **The furnace blower may be operated continuously or be controlled by a cooling thermostat located near the main return.** The thermostat should be wired so that it turns the blower on — but not the furnace — when temperatures rise above a comfortable level. Multi-speed blowers give the system more flexibility.

Sizing

It is important not to underestimate the airflow needed to maintain comfortable temperatures in the passive solar areas.

Rule of Thumb for Sizing

- **Where it is necessary to use mechanical circulation to reduce overheating, 20 to 40 litres per second should be provided for every square metre of solar aperture.** A standard furnace fan is generally adequate. The analysis tool GRAPHEAT, or standard engineering procedures, should be used to determine airflows for final design purposes.

Ventilation

Like other houses, passive-solar houses need ventilation during the winter months to maintain good air quality. In the summer, ventilation is required for cooling. Many energy-efficient houses have central, fully ducted, mechanical ventilation systems that supply fresh air to the house and exhaust stale air. Because the airflow rates required for ventilation are considerably lower than those needed to distribute passive solar gains, ventilation systems are not an appropriate method of distributing solar heat. However, a central ventilation system with a heat recovery ventilator (HRV), is a good way to provide better indoor air quality in a passive solar home. Monitored R-2000 houses with HRVs have been found to have lower levels of indoor air contaminants than conventional houses without automatic forced ventilation systems.

Rules of Thumb for Ventilation

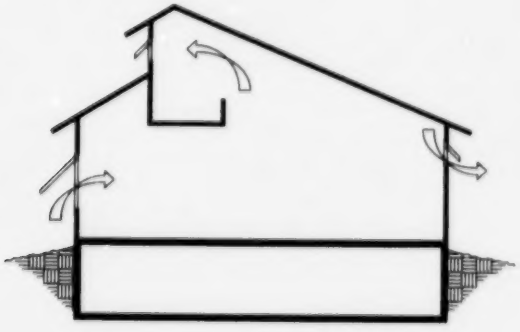
A properly designed and installed central ventilation system with a heat recovery ventilator (HRV), is recommended practice.

Summer cooling ventilation is most easily handled by operable windows. Ideally, these are located so that the prevailing summer breezes assist natural circulation; air enters the house low on the windward side and exits high on the leeward side. If this is not feasible, it is usually possible to arrange for good cross-ventilation so that air moves diagonally across each room. See figure 12.

Windows should be opened at night and closed during the day in hot weather.

Air-conditioning can replace natural ventilation during the cooling season, in which case mechanical ventilation is needed to provide fresh air.

Figure 12. Summer Ventilation



Natural ventilation may be achieved using low and high operable windows and windows located to direct breezes.

Summary

Good heat distribution is essential to passive solar design. It is achieved by the following means:

1. a design that allows as many rooms as possible to receive direct sunlight;
2. a design that allows air to circulate naturally from areas receiving the most sunlight to areas receiving the least;
3. a forced-air heating system or other mechanical equipment that assists the natural circulation process if necessary;
4. the use of thermal analysis tools to estimate the required airflow rates and to size equipment.

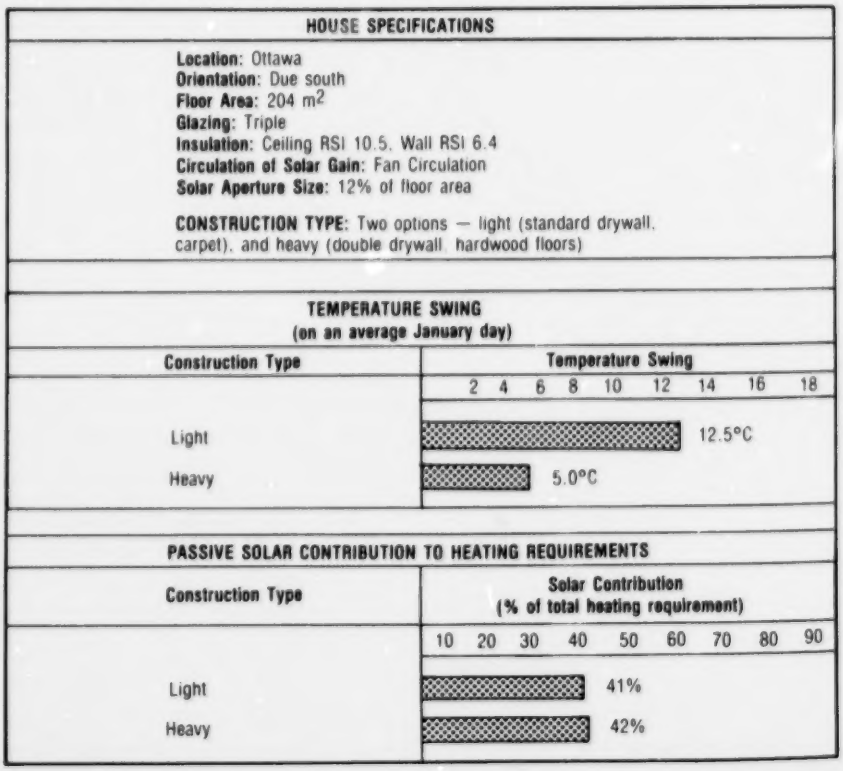
4.Storing Solar Heat

The previous chapters dealt with the collection and distribution of solar heat for immediate use within the house; the other essential component of a passive solar system is thermal storage. When sunlight is converted to heat within a material, that material functions as thermal storage. Lightweight building materials have little thermal capacity and radiate the heat to the room almost as soon as they receive it. Massive materials absorb the heat and release it slowly. The presence of thermal storage materials in rooms receiving sunlight reduces the size of the temperature swing and stores passive solar heat until later in the day. Adequate thermal storage is necessary in a passive solar house to keep temperatures comfortable and provide heat during non-solar periods.

Storage Materials

The amount of heat an object can store is principally related to its size and its heat capacity. The more thermal mass that is provided, the more storage that is available. It is important, however to ensure that the material not only has a large storage capacity but also that it is able to conduct heat readily to its interior. Dark colours absorb and radiate heat better than light colours but reflect light poorly. Generally, light colours are preferable for good light distribution, even though they offer a marginally less effective thermal storage capability. The exception might be a dark-surfaced feature wall in a well-lit building.

Figure 13 The Effects of Providing Heat Storage



With light construction, the temperature swings produced by a solar aperture sized at 12% of the floor area are excessive. The same solar aperture produces acceptable temperature swings in a house with heavy construction because the heavy construction provides heat storage. In other words, the heavy construction makes it possible to increase the solar aperture size. As a result, the solar contribution rises to 42% of heating requirements, compared with 28% for a solar aperture of 6% of floor area. However, this large increase in solar contribution does not result in a significant reduction in space heating load since the additional heat loss of the larger glass area offsets the increased solar gain. High performance windows with triple glazing are necessary for achieving large energy savings using increased solar aperture and mass.

Plasterboard provides a low-cost thermal storage material and is the most convenient and practical material to use in most situations. Simple thermal analysis tools generally assume an interior plasterboard finish. The thermal capacity of plasterboard may be increased by using a thicker board, by using a double layer or by applying plaster over the plasterboard. These techniques are sometimes used in conventional houses because they are considered to provide a superior finish.

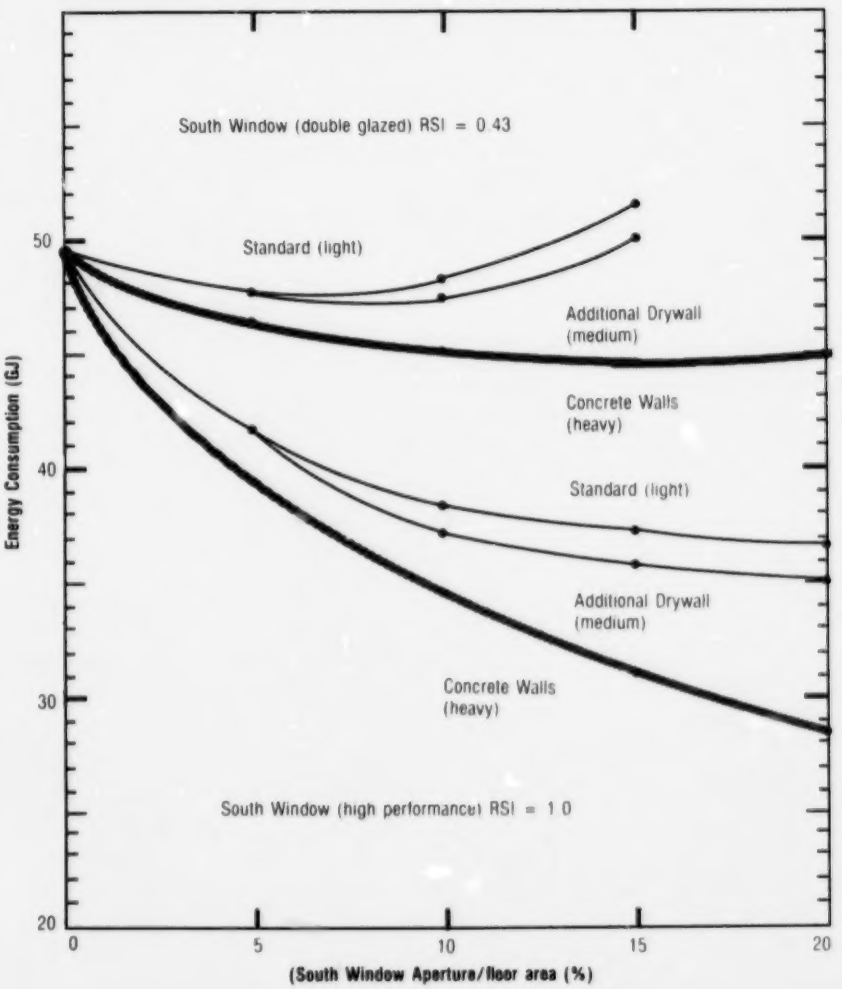
Masonry — that is, brick, stone and ceramic tile, provides good thermal storage. Ceramic tile floors may be used in south-facing rooms. Brick or stone feature walls have often been used to augment the thermal storage in a passive solar house.

Water has excellent heat storage characteristics but is not the easiest material to incorporate in a room. In greenhouses, water containers are sometimes stacked against the back wall, and freestanding translucent tubes filled with water have also been used. Decorative, water-filled containers have been used in living spaces as thermal storage. Indoor swimming pools make good thermal heat sinks. Hot tubs and spas do not work effectively as direct storage because the water is maintained considerably above room temperature.

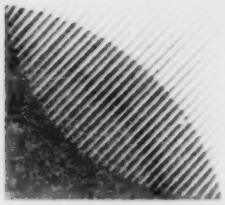
Phase-change materials (PCMs) absorb heat as they change from a solid to a liquid or from one solid crystalline form to another, and release heat when they change back to their original form. When a material melts, it absorbs heat from its surroundings, yet its temperature does not change. For example, a glass of ice water in a warm room will absorb heat from the room, which causes the ice to melt. The water temperature, however, will stay the same, 0° C, until all the ice has melted.

Materials that "melt" at room temperature can be used to store solar heat. The advantage of PCMs in a passive solar house is that they can store much more heat per unit volume than materials that rely on mass alone, and they do it with little increase in temperature. The PCMs used for passive solar storage are usually waxes or mixtures of mineral salt crystals and have been sold in manufactured modules. Manufacturers are currently investigating the feasibility of incorporating PCMs in common building materials such as plasterboard and concrete block. If this research is successful, phase-change-enhanced thermal storage is likely to be an excellent method of achieving increased passive solar contributions. See figure 14.

Figure 14. Effect of Thermal Mass on Building Energy Consumption (Low Heat Loss Windows)



Note that with double glazed windows (RSI 0.43) the addition of mass improves energy savings but there is no significant savings beyond 6% south window/floor. With high performance windows, additional mass contributes to savings well beyond 10% but control of temperature swings becomes a problem.



STORING SOLAR HEAT

Rules of Thumb for Selecting Storage Materials

- **For increased comfort, use thicker than normal plasterboard in the south zone of the house.**
- **If massive masonry materials are to be used as finishes for aesthetic reasons, it makes sense to place them so that they also function as thermal storage.**
- **In general, water is best used as remote storage in conjunction with a heat pump.**

Storage Location

A practical arrangement is to design the house so that rooms receiving direct sunlight contain additional thermal storage materials. A double layer of plasterboard is often used for this purpose; decorative elements such as a masonry fireplace may also be incorporated. If further storage is required for excess solar gains and to control temperature swings, forced-air blowers may be used to drive solar-heated air to remote storage locations.

Rules of Thumb for Storage location

- **Storage materials are most effective if placed in direct sunlight.**
- **The larger the surface area the better; large, thin sheets of heavy materials are preferable to small areas of thick (over 100 mm) material.**
- **Thermal storage materials become ineffective when they are covered with insulative materials such as carpet.**

Mechanically Enhanced Storage

If the design requires more thermal storage than can conveniently be accommodated in the solar zone of the house, additional storage may be placed elsewhere.Thermal storage can be made to function effectively away from direct sunlight provided sufficient heat can be moved to the storage. This heat transport usually requires the use of blowers and ductwork to move large volumes of solar-heated air from the south zone of the house to the storage location. Depending on the type of storage, stored heat may be released by passive discharge or by mechanical means. See figure 15.

Air-coupled remote storage. Either massive materials such as concrete and crushed stone or phase-change materials are used for this type of storage. The material must be at a lower temperature than the air used to heat it and must be warmed above room temperature before the heat can be used for space heating. To charge the storage, warm air must flow over the surface of the mass; the greater the surface area exposed to the heat, the faster the heating process. Extra-thick or double plasterboard applied to the north zone of the house is a practical type of remote storage, particularly if thick plasterboard is also required for other reasons.

Basement storage. Since most houses have concrete or block basements, it would be convenient to use this mass for thermal storage; however, there are problems with this approach. Condensation may occur on the surface of the concrete if basement temperatures are much lower than the solar-heated air and humidity levels are high. If a basement or crawl-space is fully insulated on the exterior and under the floor to reduce heat loss and risk of condensation, it may be treated as a pressurized plenum and used to store heat. This solution is useful in some circumstances.

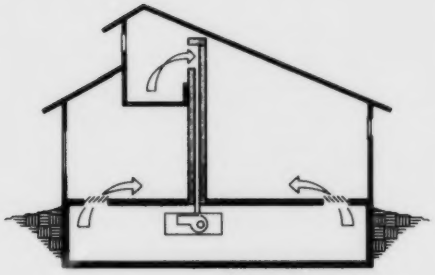
Rock bins have been used for thermal storage and may be appropriate for greenhouses or sunspaces where wide temperature fluctuations are experienced. **Hollow core concrete slabs** have also been used. In this system, the warm air is blown through the hollow floor slab, which becomes warm and eventually warms the rooms above and below. Either type of storage is unlikely to be cost-effective, although its utility is increased if a second heat source, preferably of relatively high temperature, such as a wood stove, is used to charge the storage when solar heat is unavailable.

Heat-pump-augmented Storage

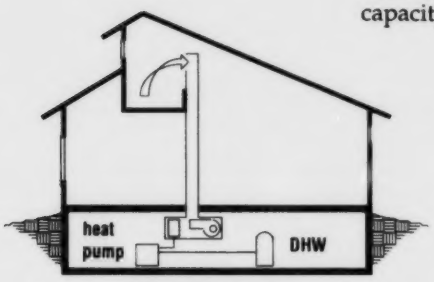
Water is one of the most efficient thermal storage materials and a heat-pump is a highly effective means of transferring solar gains to water storage. Another advantage of heat-pump-augmented storage is that the heat-pump upgrades low temperature passive solar heat to much higher temperatures that can then be used for a variety of purposes. Heat-pumps enable solar heat to heat domestic hot water, to provide hydronic space heating or to heat swiming pools and indoor spas. A heat-pump produces cooling as a by-product of the heat transfer process. This cooling is convenient for passive solar applications because the cool air may be used to offset any overheating during solar gain periods. See figure 15.

A few manufacturers offer air-to-water heat-pumps suitable for passive solar homes. A passive solar installation is unlike a conventional air-to-air heat-pump in that it draws warm air from inside the house and transfers the heat to water storage. The system configurations differ by manufacturer but the pump itself is not normally reversible; the heat is extracted from the hot water tank as the hot water is drawn off, in the case of domestic hot water, or is pumped through a fan coil unit or radiators for space heating. While it is not necessary for most passive solar houses, heat-pump-augmented storage is an important tool for the designer who wishes to maximize passive solar contributions.

Figure 15. Mechanically Enhanced Storage



Solar gains may be stored by circulating warm air through thermal mass and distributing it throughout the house



Heat pumps may be used to extract heat from room air and use it to heat hot water or store it for space heating

Summary

Thermal storage is required in every passive solar house. If the house has a modest amount of south glass, standard building materials may provide sufficient mass but often additional storage is required. There are several methods of providing storage and it may be more convenient to use two or more techniques in the house rather than attempt to meet all storage needs with one material. The following points may assist the selection of storage methods:

1. The first step is to increase thermal mass in rooms receiving direct sunlight. Thicker-than-normal plasterboard, ceramic tile floors and masonry feature walls may be used.
2. If analysis shows that more storage is required, mechanically assisted remote storage may be used. Heat-pump systems using water as a heat sink have the greatest storage capacity.

5. Design Integration

The one thing that makes or breaks any house design is the way in which the various functions and systems fit together to make an architectural whole. This fit is particularly true of a passive solar design, which must incorporate solar collection, air circulation and thermal storage along with all the other items needed in the house. Careful foresight rather than capital expense is needed to make a passive solar design work, and the thermal analysis tools now available to the designer make the task relatively easy.

Interior Layout

The interior layout of a house affects the way the passive solar components work. The following rules of thumb summarize the points raised in previous chapters.

Rules of Thumb for Interior Layout

- **As much of the house as possible should receive direct sunlight.** In particular, the primary living space — living rooms, dining rooms, great rooms and family rooms — should receive direct sunlight.
- **Open planning, rooms that extend the entire depth of the house from north to south, open stairwells, and double-height atriums help to distribute heat and sunlight through the house.** Houses in which most of the lower floor is open to spaces above it will, however, tend to be warmer upstairs than down unless fans or blowers are used to distribute the air.
- **Interior masonry feature walls should be located in the south zone of the house in rooms receiving direct sunlight.**
- **Windows should be kept to a minimum on the north elevation.** Large expanses of west-facing glass should be avoided. Windows on the other walls should make best use of the glass area; for any given frame opening, one large window performs better than several small ones. Highly insulative glazings give better overall performance than conventional glazings.

Matching Collection, Circulation and Storage

These three variables — collection, circulation, and storage — must match. It is useless to have a large expanse of south-facing glass with no air circulation and no thermal storage, because the south part of the house will overheat. Conversely, high-volume blowers and massive masonry feature walls will accomplish nothing if there is insufficient south window area or if the glass is shaded. The rules of thumb regarding collection, circulation and storage should be followed for a design that is close to the mark. Thermal analysis is then used to fine-tune the plans.

Heating, Cooling and Ventilation System Considerations

A passive solar house requires an auxiliary heating system when solar energy is not available and passive solar storage has been depleted. Depending on the design, about 60 to 75% of the annual space heating requirements will normally be supplied by the auxiliary heating system. Any medium- or high-efficiency heating system may be installed in a passive solar house. The choice of heating system is dependent on the house design; some heating choices are listed below.

Baseboard electric resistance heaters may be the best choice for a well-insulated, modest, low-load/low-gain house with good natural air circulation.

If natural air circulation is insufficient, **a forced-air furnace** can do double duty by providing auxiliary heat and air circulation; a further advantage of a fully-ducted heating system is that the ducts can also be used to distribute fresh ventilation air.

In houses with low heat loads, **domestic hot water tanks** have been used to provide both hot water and space heating by a hot water line running from the tank to a **fan-coil unit** which distributes warm air to the house through a conventional duct system.

Radiant heating panels can be useful, particularly in sun rooms, where they can be used at night to offset any discomfort caused by large expanses of glass.

Elaborate house designs with much glazing and luxury features such as spas or swimming pools generally require elaborate mechanical systems. Both indoor and outdoor swimming pools have been used as heat sinks, or thermal storage, in conjunction with **water-source heat pumps.**

All passive solar houses require some form of air circulation during collection periods to distribute warm air about the house and to cool the south zone of the house. This **"passive cooling"** will in most cases be adequate all year — a well-designed passive solar house should not become too warm in any season. During the summer, windows may be opened at night to cool the house and closed, with curtains and blinds drawn, during the day. If air-conditioning is required, an air-to-water heat pump may be appropriate. Some of the new systems can be set up to supply space heating and hot water, cooling and thermal storage.

A forced-ventilation system is needed to supply fresh air to the living space and to exhaust stale air. A convenient way to get an energy-efficient central ventilation system is to install a **heat recovery ventilator (HRV).** Balanced-flow HRVs heat incoming fresh air with outgoing stale air ducted from bathrooms and kitchens. **Exhaust-only ventilation systems,** which employ heat-pumps to recover heat, are also available; fresh air must be introduced separately with these systems. Several publications on house ventilation and HRVs are listed in the reference section at the back of this book.

Energy-efficient Envelope Design

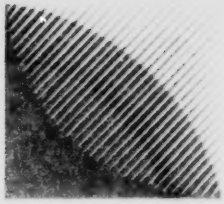
A passive solar house must also be an energy-efficient house if it is to function properly. The exterior envelope (foundations, walls and roof) must be well-insulated with minimal thermal bridging through assemblies, and must be highly resistant to air-infiltration or exfiltration. Several good techniques for building energy-efficient wood frame housing have been developed in recent years and have been described in detail in the publications listed at the back of this book. It is most important that both the designer and the builder be thoroughly familiar with energy-efficient construction practice. Optimum insulation levels for a particular design depend on many factors, including fuel cost, materials cost and desired payback period. Thermal analysis will help to determine the best strategy.

Design for Comfort— A Comfort Checklist

Comfort involves a number of variables, not the least of which are the occupants themselves, each of whom may have different ideas about ideal temperatures, humidity and lighting levels. If the house and its mechanical system have been properly designed, however the occupants should be able to control the indoor conditions to suit themselves.

Winter overheating

No part of the house should become uncomfortably hot during the heating season. A balance must be found between solar aperture size, heat storage capacity and air circulation. In particular, the latter should distribute the solar gains and prevent hot spots from developing.



Summer overheating

The passive solar house should be designed to function without air-conditioning in the summer. The glazing should be equipped where necessary with awnings, overhangs and blinds. Operable windows should be located to facilitate good cross-ventilation and the house layout should provide good natural air-circulation. If air-conditioning is required, it may be added to the forced-air heating system, as in a conventional home. If an air-to-water heat-pump is part of the mechanical system, it can be used to provide air conditioning.

Winter chilling

The house should not become uncomfortably cool at night. The thermal envelope must be well-insulated and precautions should be taken to prevent localized cooling at windows. Radiant heat loss through glass at night can cause discomfort to people sitting close to the windows, even if air temperatures are high. The cool glass surface also tends to create convection currents, which are perceived as drafts, even if the window is airtight. The use of blinds and drapes may cure this problem. Alternatively, wall- or ceiling-mounted radiant heating panels may be used as supplementary heaters to counteract the effect of radiant losses through the glass. Highly insulated glazings are less likely to cause discomfort than conventional glass.

Air movement

Forced-air circulation should not create discomfort. Moving air feels cooler than still air at the same temperature. Therefore, when a fan is being used to move air at room temperature about the house, the occupants may perceive the air movement as drafts, especially if they are seated near a floor register. Drafts may be prevented by placing the supply registers in the ceiling or high in the wall. Air-conditioning diffusers rather than heating register grilles help to disperse the moving air in a draft-free manner.

Humidity control

The house should have moderate winter humidity levels, about 40% RH. Air with a high relative humidity feels warmer than dry air at the same temperature and permits the thermostat setting to be lower, but very high relative humidities are uncomfortable and may lead to condensation damage on the windows and other surfaces. Energy-efficient construction practice reduces unwanted natural air-infiltration and raises indoor winter humidity levels. The controlled ventilation system provides an effective means of adjusting indoor humidity; if humidity levels are too high, the ventilation rate is increased, if they are too low, the ventilation rate is decreased. Adjustment of the ventilation rate should result in comfortable conditions in the majority of houses.

In the case of large houses, or houses without children where the occupants are at work all day, humidity levels are sometimes too low, even after ventilation rates have been decreased. Lifestyle changes, such as the addition of house plants to the home and the venting of electric clothes dryers indoors, may solve the problem. If not, a humidifier can be used. Excessive humidity is unusual and may be a sign that the ventilation system is undersized or malfunctioning.

Air Quality

The air inside the house should be perceived as "fresh" rather than stale with lingering odours. Fireplaces must be equipped with a ducted outside air supply and glass doors to reduce the risk of combustion products entering the living space. The new high-efficiency gas or oil furnaces and boilers, which have a fan to maintain draft, or have a sealed combustion air intake, avoid the possibility of backdrafting or spillage of the products of combustion. It is good practice to seal basement cracks and floor drains to prevent the entry of radon or other soil gasses. The ventilation system should be designed to supply fresh air to the whole living space, especially to living rooms and bedrooms. Stale air should be exhausted from kitchen, bathrooms and hobby areas before it contaminates the rest of the house. Paint and other construction materials should be allowed to cure and the house should be thoroughly ventilated to remove all odours prior to occupancy. Air filters can be installed in the ventilation system for people particularly sensitive to dust, pollen and other particulates.

Glare

The house should be designed to reduce discomfort from glare. Glare may be a problem in rooms with very high lighting levels but it more commonly occurs in rooms with high lighting contrast, particularly if the subject is focussing on an object in shadow against a bright background such as a window. The risk of glare is reduced if windows are placed on more than one wall to provide cross-lighting. Walls adjacent to windows should be finished with light colours to reflect light. Reading and sewing rooms and studies should be organized for even light distribution.

Summary

Much of the information in Part 1 represents good design practice for any house, but the passive solar designer, or the potential owner of a passive solar house must pay particular attention to the integration of passive solar features into the house and their likely overall effect on the various comfort parameters. This concern is necessary partly because a passive solar house should have superior comfort and energy performance, and partly because failure to balance collection, distribution, storage and the other aspects of energy-efficient design can result in occupant discomfort and unnecessarily high energy use. Analysis tools should always be used to assess the performance of a design prior to construction.

Further Information on Thermal Analysis Tools

GRAPHEAT is a simple method for quickly estimating passive solar performance. The GRAPHEAT method is described in two CMHC publications: GRAPHEAT and GRAPHSHADE, available from Canada Mortgage and Housing Corporation.

HOT-2000 (early versions are known as HOTCAN) is the easiest to use and quickest of the available microcomputer programs. HOT-2000 is available from the Canadian Home Builders' Association, Suite 502, 200 Elgin Street, Ottawa, Ontario K2P 1L5

ENERPASS is a computer program which gives hour by hour simulations in addition to seasonal totals. It is suitable for analyzing complex designs or for checking outputs from other programs, particularly when unusual design strategies are employed. ENERPASS is available from Enermodal Engineering, 368 Phillip Street, Unit 2, Waterloo, Ontario N2L 5J1.

HEAT RECOVERY VENTILATORS. Performance comparisons can be made between units on the market by use of test results in accordance with CSA Standard 439. Installation should be in accordance with CSA 444. Information may be obtained from The Heating, Refrigeration and Airconditioning Institute of Canada, 5468 Dundas Street West, Suite 226, Islington, Ontario M9B 6E3.

About The Designs

The 24 house designs presented in Part 2 were developed by Canadian architects and designers for use in Canadian cities. Each house makes deliberate use of the sun's energy to provide heat, with the total solar contribution ranging from 14 to 30 gigajoules* per house.

• The designs are being presented here for three principal reasons:

• The designs offer excellent housing possibilities for a wide variety of needs.

• Those readers who do not find a design that meets their needs are sure to find design ideas that might provide inspiration or assistance to them.

• Even those who are not planning to build will find that the design concepts presented here help illustrate and clarify some of the passive solar requirements that were discussed in Part 1.

Each of the 24 designs is presented in a standard format; this format is described on the next pages.

* Gigajoule is a metric unit of energy: 1 GJ = 278 kw•h

First Page

About this Design

This section provides an overview of the house design, including some of its more interesting features (but excluding passive solar elements).

Major Solar Features

This section highlights the passive solar features of the house design. In each case an energy performance table is included. This performance table is explained in detail below.

Illustrations

The first illustration for every design presents a view of the house as it is seen from the street. The illustrations lower on the page provide additional details on the appearance of the home, with notations focussing on the solar features.

Second Page

Floor plans of each unit and explanatory comments are included here. Basement floor plans are not shown unless some important part of the house design is in the basement.

In most cases, house plans are arranged so that the ground floor is at the bottom of the page, the main entrance to the house parallel to the foot of the page. Second and third floors are positioned on the page above the ground floor plan. (In the case of a few townhouses, the shape of the structures have made this layout impossible. In all these cases, the main entrance to the house is oriented to the right-hand edge of the page.

A B O U T T H E D E S I G N S

The scale for all floor plans is the same and is shown on the page. The scale of all other drawings varies.

In all cases, a symbol on the page indicates the direction of South, that is, the direction in which most of the house's windows face.

All the drawings on the following pages were prepared by architects and designers.

It should be noted that the designers of the individual homes prepared most of the drawings for their designs. Although there are not huge variations in drafting style, there are, inevitably, small differences from architect to architect. To keep the flavour of individuality, these differences have been retained in the drawings.

The Performance Tables

Each design write-up contains a small table that shows the energy performance of the house in various locations (three or four locations). Because of the importance of these numbers, it is essential to understand their meaning.

The first column lists the locations: Vancouver, Ottawa, Regina and, in some tables, Toronto. These cross-Canada locations were chosen to show the variations in energy performance.

The second column presents **annual energy consumption for space heating** in gigajoules, a metric unit of energy. These numbers provide a basis for comparing the heating costs for the different house designs. The box on the next page, Converting Gigajoules to Energy Costs, explains how to arrive at an estimate of likely heating costs.

Note that the gigajoule figures given in the second column relate to heating costs after solar gains have been taken into account: in other words, net energy use.

The third column presents the **solar fraction.** This figure is defined as the ratio of the amount of solar energy utilized for space heating to the total annual heating energy requirement (excluding the solar gain). A value of 25% is often considered a good design target; a figure over 25% signifies the efficient use of passive solar energy for space heating.

The fourth column presents the temperature swing likely to occur during a clear, sunny winter day. A variation in temperature of less than 6°C is unlikely to cause any discomfort, unless the house temperature is not set back at night. (In such cases a temperature swing of 6°C implies indoor temperatures as high as 26°C.) Temperature swings of 7°C or more are generally unacceptable, particularly if these temperatures are maintained for any length of time.

The energy requirement, solar fraction, and temperature swing were all calculated by means of *Grapheat* (see Further Reading). It must also be stressed that the estimates assume the following:

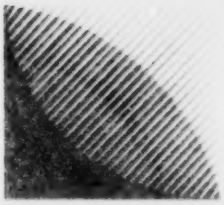
- the house is being made energy efficient to the standard defined in *Measures for Energy Conservation in New Buildings 1983;*
- there is good circulation of solar gain within the house;
- there is no additional storage mass, unless specifically indicated in the write-up.

All these houses were designed for a specific city (indicated in boldface for each design). The houses will perform well in the city for which they were designed. If the house is to be built elsewhere, the performance should be checked against *Grapheat* or a suitable computer program. Some minor modifications to the design may be required to ensure that optimum use of solar gain is made. For instance, the design may produce excessive temperature swings in climatic zones where more solar energy is available than in the original location for which the house was designed. On the other hand, increased window area may be desirable in other locations.

The importance of location is illustrated in the performance figures presented in the following 24 designs. In estimating the solar fractions and temperature swings, no adjustment to the house design was made as the house was "relocated" (except insulation levels, which were adjusted in accordance with *Measures 1983*, which specifies different levels depending on the local climate).

The result of relocation is sometimes overheating. In these cases, south-facing window glass area should be reduced, or thermal storage provided, if the design is to be used in a location in which overheating could occur.

Table 2 summarizes the performance of the 24 designs presented in this book.



Converting Gigajoules to Energy Costs

The performance tables in this manual indicate the total amount of supplementary energy required to heat each of the house designs — but the energy is expressed in gigajoules, a metric unit of energy. This is an appropriate way to express heating requirements, since it will be correct no matter what energy source is used or what type of heating system is used. However, the gigajoule is not a widely understood unit.

It is simple to convert gigajoules to energy costs, but to do so it is necessary to know the following:

- Local energy rates, which should be available from the local energy supplier.
- The seasonal efficiency of the heating system to be used, which should be available from the heating system supplier. If not, one of the efficiencies presented in Table 1 may be used.

Table 1

Seasonal Efficiency of Various Heating Systems

Heating System	Seasonal Efficiency
Regular gas furnace (pilot light)	67
Gas furnace with spark ignition	70
Gas furnace with ignition and damper	75
Gas furnace (medium efficiency)	80
Condensing gas furnace	93
Regular oil furnace	65
Oil furnace (medium efficiency)	75
Electric furnace (w baseboard heaters)	100

With this information, appropriate energy costs can be calculated as follows:

For oil:
Energy cost = number of gigajoules required to heat the home
x 0.004
x seasonal efficiency of the furnace
x cost of oil per litre

For gas:
Energy cost = number of gigajoules required to heat the home
x 0.0037
x seasonal efficiency of the furnace
x cost of natural gas per cubic metre

For electricity:
Energy cost = number of gigajoules required to heat the home
x 0.0036
x seasonal efficiency of the heating system
x cost of electricity per kilowatt hour

Table 2 Summary of Performance of 24 Passive Solar Designs

DETACHED

Design	Orientation of front of house	Floor area (excluding basement and garage) m²	Annual space heating energy consumption (for an Ottawa location) GJ	Annual space heating energy consumption (for an Ottawa location) GJ per m² of floor area	Solar fraction (for an Ottawa location) %	Temperature swing (for an Ottawa location) °C
1	S	137	56.5	0.41	23.9	1.1
2	N	148	58.1	0.39	27.5	1.9
3	N	150	57.7	0.38	19.1	0.3
4	S	150	57.0	0.38	22.5	0
5	S	135	53.5	0.40	32.8	7.1*
6	N	148	56.4	0.38	28.7	3.8
7	S	143	66.0	0.46	35.3	10.4*
8	N	139	51.5	0.37	33.6	6.7*
9	N	142	54.5	0.38	36.4	10.1*
10	S	142	59.6	0.42	30.3	7.0*
		AVERAGE	57.1	0.40 (based on 9 designs)	29.0	4.8

SEMI-DETACHED

Design	Orientation of front of house	Floor area (excluding basement and garage) m²	Annual space heating energy consumption (for an Ottawa location) GJ	Annual space heating energy consumption (for an Ottawa location) GJ per m² of floor area	Solar fraction (for an Ottawa location) %	Temperature swing (for an Ottawa location) °C
11	N	121	42.7	0.35	26.1	1.5
12	N	122	43.9	0.34	30.1	5.0
13	S	129	46.3	0.36	23.8	1.8
14	S	139	55.6	0.40	23.3	1.0
15	S	144	52.2	0.36	27.5	6.8*
16	N	154	58.6	0.38	26.2	2.5
17	S	142	43.0	0.30	29.4	1.2
		AVERAGE	48.9	0.36	26.6	2.8

TOWNHOUSES

Design	Orientation of front of house	Floor area (excluding basement and garage) m²	Annual space heating energy consumption (for an Ottawa location) GJ	Annual space heating energy consumption (for an Ottawa location) GJ per m² of floor area	Solar fraction (for an Ottawa location) %	Temperature swing (for an Ottawa location) °C
18	S	134	38.6	0.29	28.8	6.8*
19	N	104	31.6	0.30	27.7	6.0
20	S	110	32.2	0.29	24.8	1.9
21	S	116	30.8	0.27	25.3	3.0
22	S	119	31.6	0.27	29.3	3.9
23	S	118	29.4	0.25	34.4	3.6
24	N	119	31.4	0.26	31.4	5.0
		AVERAGE	32.2	0.276	28.8	4.3
				OVERALL AVERAGE OF SOLAR FRACTION	28.0	

Note: Temperature swings of 7°C or more are generally unacceptable and should be avoided.

From table 2, it can be seen that:

On average the designs have a solar fraction of 28%, ranging from a low of 19.1% to a high of 36.4% (when Ottawa is used as the base for calculation).

In most cases, the solar fraction is provided without its producing unacceptable temperature swings. In a few cases, however, adjustments would be required to prevent overheating if the design were to be used to build a house in Ottawa. (None of the designs produce overheating in the locations for which they were originally intended.)

On average the detached houses require 57.1 gigajoules (GJ) annually for space heating, representing an average of 0.4 GJ per m^2 of floor area. As might be expected, the semi-detached houses require less space-heating energy. Specifically, the seven semi-detached designs require an average of 48.9 GJ annually, the equivalent of 0.36 GJ per m^2 of floor area.

Again, as expected, the lowest energy requirements are for the townhouses. The seven units presented here require only 32.2 GJ annually on average. This works out to be 0.27 GJ per m^2 of floor area, well below the requirements of the semi-detached and detached houses.

Choosing A Plan

Selecting a house design can be a complicated process. It is important to consider a host of factors other than the energy performance: family size, family needs, family lifestyle, cost of construction, special needs such as access for disabled people, if applicable, exterior appearance, and much more. Anyone who has not been involved in the house design process should take the time to learn something about these various factors before selecting a design. There are many publications that can assist in that learning process; some are listed in Further Reading at the end of this book.

Not all the designs presented in this book will be suitable for all possible situations. For instance, the size of the units varies considerably, from 104 to 157 m^2. Some are townhouses, some are semi-detached, and some are detached houses. All are designed for east-west streets; some are designed for the north side of the street and others for the south side. Even the solar performance of the units varies.

In choosing a design, it must be remembered that the designs presented here can easily and readily be changed. For instance:

- If the lot allows, the dimensions of the units can be increased or, conversely, decreased, within limits.
- The level of passive solar contribution can be adjusted by increasing or decreasing the size of the south-facing aperture. To compensate, generally increased mass must be provided or other measures be taken. Where the house is to be built in a climatic zone other than the one for which it was designed, these types of adjustments may also be essential to maintain comfort levels and to ensure optimum use of the sun.
- The interior floor plans can also be adjusted. Room sizes may be changed, or even the relationship of one room to another. The changes must, however, be carefully done so as not to adversely affect the solar characteristics. In addition, attention must be paid to traffic flow patterns, minimum comfortable room sizes, and other features that have been carefully balanced by the designers of the current plans.

In short, although the designs presented here are "ready to build," they can be adjusted, within limits, to meet special needs. Whether the houses are to be built "as is" or with modifications, it is strongly recommended that detailed working drawings and specifications be prepared by a professional before construction begins. Such drawings will be required to obtain building permits, and are essential if the house is to be properly built.

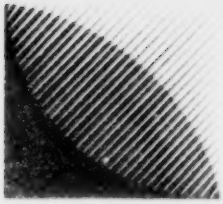
Construction Details

In Part 1 of this book, it was recommended that passive solar homes be built to the level of energy efficiency recommended in the National Research Council of Canada publication *Measures for Energy Conservation in New Buildings 1983*. The performance estimates for the following 24 designs assume that the houses have been built to this level of efficiency.

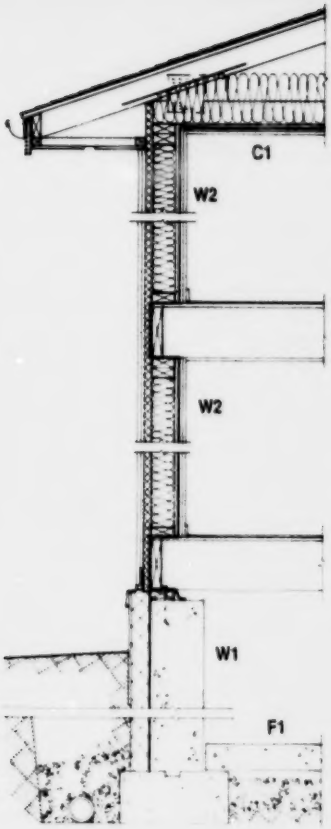
Therefore, because construction details are not presented in the following designs and because meeting the recommendations contained in *Measures 1983* require construction details different from conventional practice, four representative construction details for four different climatic areas are presented here. These detailed drawings are representative only; other construction techniques can be used.

It should be noted that the drawings provide reasonably high levels of insulation and a continuous layer of insulation, wherever possible, thus avoiding "thermal bridging" through uninsulated areas. In addition, the drawings show a continuous and sealed sheet of polyethylene designed to serve as both a vapour barrier and an air barrier.

For further information on basic construction practices and on techniques of energy efficient construction, see Further Reading.

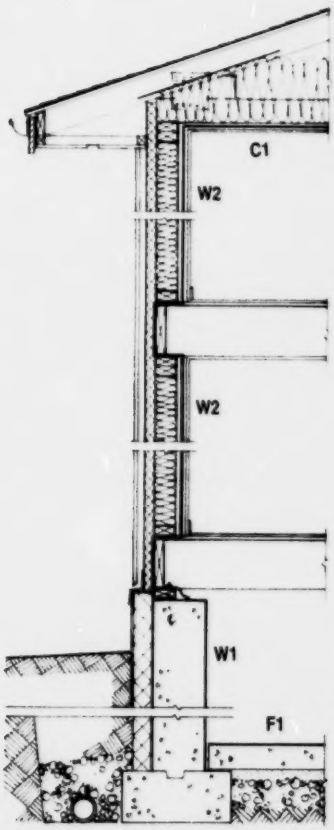


Construction Assemblies
for *1983 Measures for Energy Conservation*
Standard-Frame Construction
for Locations up to 3500 C (dd)
Example: Vancouver, B.C.



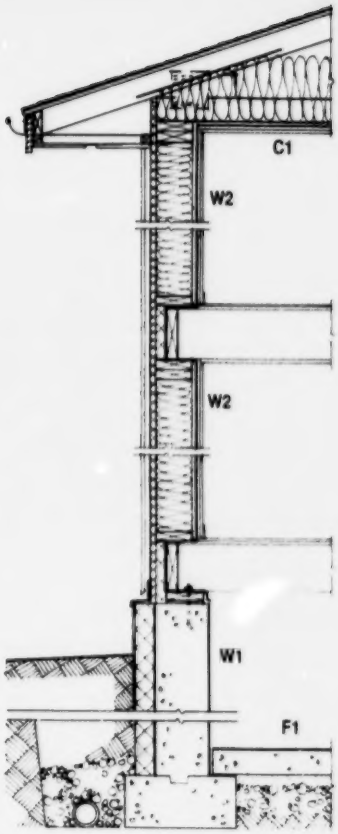
ASSEMBLY CODE	THERMAL RESISTANCE OF ILLUSTRATED ASSEMBLY C° m²/W	REQUIRED THERMAL RESISTANCE OF ASSEMBLY ACCORDING TO 1983 MEASURES FOR ENERGY CONSERVATION C° m²/W	COMPONENTS FROM INTERIOR TO EXTERIOR
F1	0.31	0.0	• concrete floor slab • 0.15 mm polyethylene vapour barrier • 125 mm crushed stone on undisturbed soil
C1	5.00	4.7	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier • wood trusses at 600 mm o.c. Note that the heel of the truss is raised to allow for a ventilation space above the insulation. • blown-in fibrous insulation (RSI 4.68) • ventilated attic air space
W1	2.60	2.2	• 200 mm poured concrete wall • wall damproofing • rigid insulation board (RSI 2.25, suitable for use below grade) mechanically fastened to wall The insulation extends to the top of the footing. • 12 mm cement parging on metal lath to 200 mm below-grade
W2	3.20	3.0	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • 39 x 89 mm @ 400 o.c. wood studs with diagonal bracing as required • fibrous batt insulation (RSI 2.1) • 25 mm rigid insulation board sheathing (RSI 0.70) • if the building is in a coastal region, provide 19 x 39 @ 600 o.c. wood strapping for a ventilated air space • wood or aluminum siding

Construction Assemblies
for *1983 Measures for Energy Conservation*
Standard-Frame Construction
for Locations between
3500 and 5000 C (dd)
Example: Ottawa, Ontario



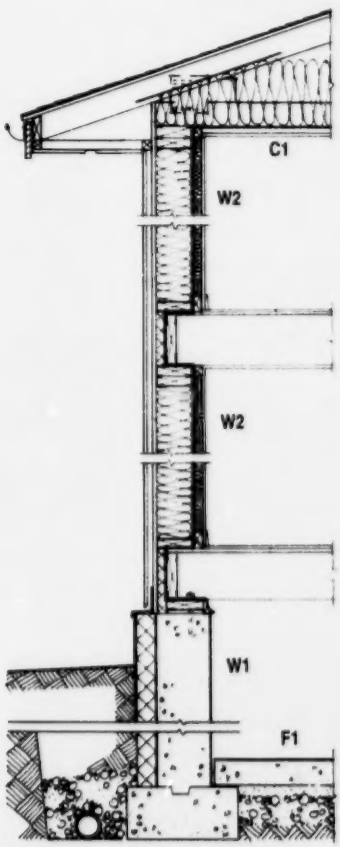
ASSEMBLY CODE	THERMAL RESISTANCE OF ILLUSTRATED ASSEMBLY C° m²/W	REQUIRED THERMAL RESISTANCE OF ASSEMBLY ACCORDING TO 1983 MEASURES FOR ENERGY CONSERVATION C° m²/W	COMPONENTS FROM INTERIOR TO EXTERIOR
F1	0.31	0.0	• concrete floor slab • 0.15 mm polyethylene vapour barrier • 25 mm sand fill • 125 mm crushed stone on undisturbed soil
C1	6.20	5.6	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • wood trusses at 600 mm o.c. Note that the heel of the truss is raised to allow for a ventilation space above the insulation. • blown-in fibrous insulation (RSI 5.85) • ventilated attic space
W1	2.60	2.2	• 200 mm poured concrete wall • wall damproofing • rigid insulation board (RSI 2.25, suitable for use below grade) mechanically fastened to wall The insulation extends to the top of the footing. • 12 mm cement parging on metal lath to 200 mm below-grade
W2	3.82	3.6	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • 39 x 89 mm @ 400 o.c. wood studs with diagonal bracing as required • fibrous batt insulation (RSI 2.1) • 39 mm rigid insulation board sheathing (RSI 1.32) • if the building is in a coastal region, provide 19 x 39 @ 600 o.c. wood strapping for a ventilated air space • wood or aluminum siding

ASSEMBLY CODE	THERMAL RESISTANCE OF ILLUSTRATED ASSEMBLY C° m²/W	REQUIRED THERMAL RESISTANCE OF ASSEMBLY ACCORDING TO 1983 MEASURES FOR ENERGY CONSERVATION C° m²/W	COMPONENTS FROM INTERIOR TO EXTERIOR
F1	0.31	0.0	• concrete floor slab • 0.15 mm polyethylene vapour barrier • 25 mm sand fill • 125 mm crushed stone on undisturbed soil
C1	6.75	6.4	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • wood trusses at 600 mm o.c. Note that the heel of the truss is raised to allow for a ventilation space above the insulation. • blown-in fibrous insulation (RSI 6.40) • ventilated attic air space
W1	2.6	2.2	• 200 mm poured concrete wall • wall damproofing • rigid insulation board (RSI 2.25 suitable for use below-grade) mechanically fastened to wall The insulation extends to the top of the footing. • 12 mm cement parging on metal lath to 200 mm below-grade
W2	4.25	4.1	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • 39 x 140 mm @ 400 o.c. wood studs with diagonal bracing as required The bottom plate extends 39 mm past the floor headers to allow for a 39 mm rigid insulation board. • fibrous batt insulation (RSI 3.52) •19 mm rigid insulation board sheathing (RSI 0.53) • if the building is in a coastal region, provide 19 x 39 @ 600 o.c. wood strapping for a ventilated air space • wood or aluminum siding



Construction Assemblies for 1983 *Measures for Energy Conservation* Standard-Frame Construction for Locations of between 5000 and 6500 C (dd) Example: Regina, Saskatchewan

ASSEMBLY CODE	THERMAL RESISTANCE OF ILLUSTRATED ASSEMBLY C° m²/W	REQUIRED THERMAL RESISTANCE OF ASSEMBLY ACCORDING TO 1983 MEASURES FOR ENERGY CONSERVATION C° m²/W	COMPONENTS FROM INTERIOR TO EXTERIOR
F1	0.31	0.0	• concrete floor slab • 0.15 mm polyethylene vapour barrier • 25 mm sand fill • 125 mm granular fill on undisturbed soil
C1	7.34	7.1	• 12 mm gypsum board • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • wood trusses at 600 mm o.c. Note that the heel of the truss is raised to allow for a ventilation space above the insulation. • blown-in fibrous insulation (RSI 7.00) • ventilated attic air space
W1	2.6	2.2	• poured concrete wall, thickness as required • wall damproofing • rigid insulation board (RSI 2.2 suitable for use below-grade) mechanically fastened to wall • 12 mm cement parging on metal lath to 200 mm below-grade
W2	5.13	4.5	• 12 mm gypsum board • 39 x 39 mm @ 600 o.c. horizontal wood strapping for electrical wiring • fibrous batt insulation (RSI 0.98) between strapping • continuous 0.15 mm polyethylene air seal/vapour barrier with acoustical sealant at all joints • 39 x 140 mm @ 400 o.c. wood studs with diagonal bracing as required The bottom plate extends 39 mm past the floor headers to allow for a 39 mm rigid insulation board. • 12 mm wood fibreboard sheathing (RSI 0.23) • if the building is in a coastal region, provide 19 x 30 @ 600 o.c. wood strapping for a ventilated air space • wood or aluminum siding



Construction Assemblies for 1983 *Measures for Energy Conservation* Strapping Wall Frame Construction for Locations over 5500 C (dd) Example: Churchill, Manitoba

DESIGN ONE

About this Design

This two-storey house is designed for the north side of an east-west street, so that the street side of the house faces south. The design provides a total floor area of 137 m², plus a basement.

On the ground floor, the sunny living room includes a decorative masonry alcove and wood stove. The kitchen is U-shaped with convenient full-wall pantry storage, and is connected to a breakfast nook and dining room. The dining room, in turn, opens onto a rear deck through patio doors.

Upstairs, the design provides for a large master bedroom with a three-piece ensuite bathroom and a walk-in closet with dressing area. Two additional bedrooms, the main bathroom, and an open landing area complete the second storey.

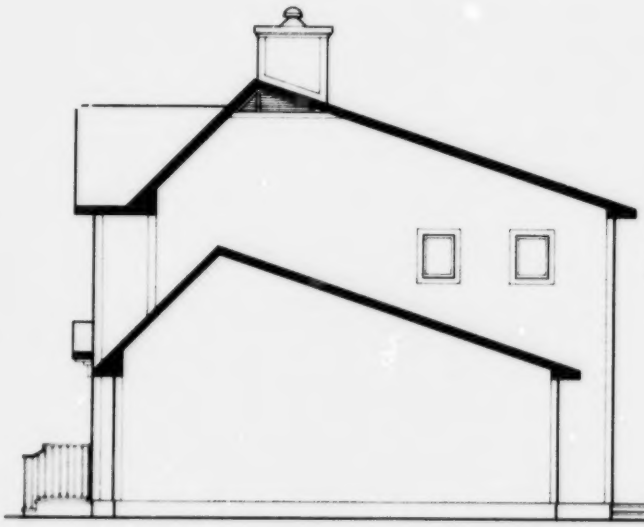
View from the Street (south side of house)

Solar Features

The house has been designed with most of the window area located on the south side, facing toward the street. Little glass area has been provided on the other sides of the house; even so, natural light is provided to virtually every room in the house.

The most striking solar feature of this traditionally elegant design is the large two-storey sun space entry. This two-storey space connects the ground floor, front hall and stairwell with the second floor.

The upper gallery is provided with a high air return for the forced-air heating system, to recirculate passive solar gain (and heat from the wood stove). The compact shape of the house simplifies circulation of solar gain, and helps keep the house energy efficient.



Few windows except on south side of house.

East Side of House

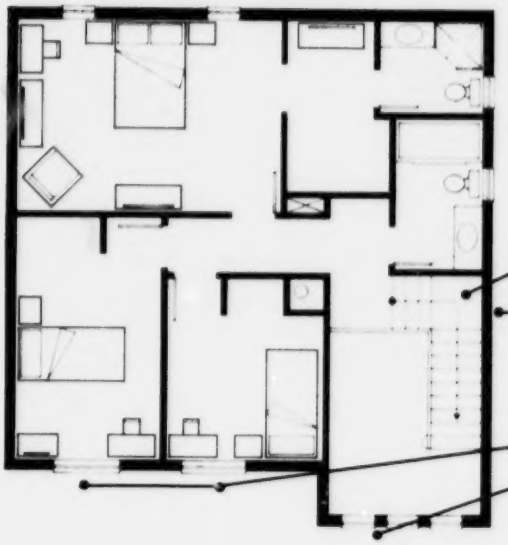
House has compact shape to maximize energy efficiency.

PERFORMANCE

Vancouver	33.0	23.7	5.0
Ottawa	36.5	23.9	1.1
Regina	67.7	29.3	0
Toronto	**48.9**	**22.9**	**2.9**

*To calculate costs, see Converting Gigajoules to Energy Costs

SECOND FLOOR

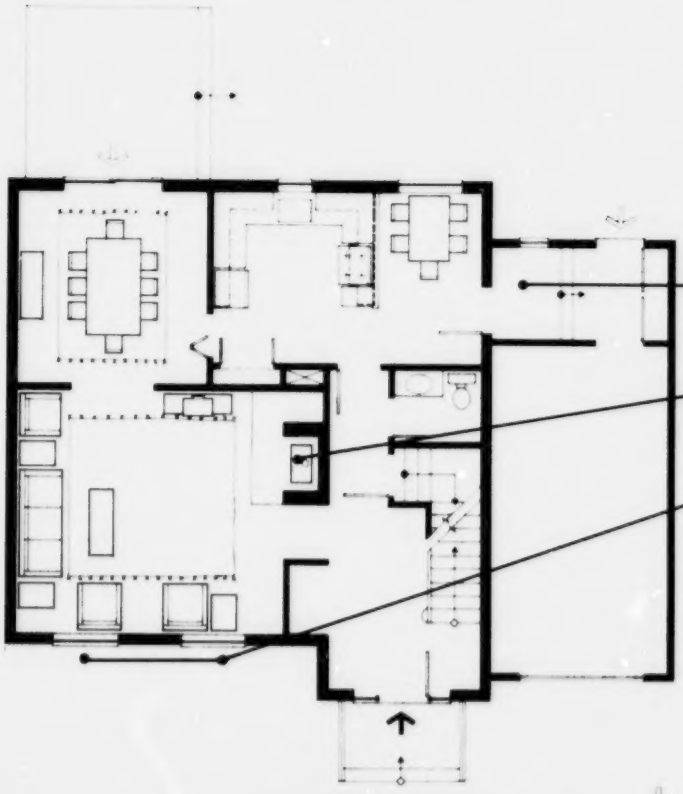


Landing overlooks two-storey sun space, providing views to the ground floor entry area and to the outside.

High-level return air inlet above sun space assist circulation of passive solar gain.

Window area is concentrated on the south side of the house.

GROUND FLOOR



Unheated airlock entry gives direct access from the kitchen to the garage and backyward.

Masonry alcove and woodstove provide visual appeal and additional heat.

Window area is concentrated on the south side of the house.

S

MAIN ENTRANCE

0 1 2 3 4

METRES

DESIGN TWO

About this Design

This two-storey house is designed for a lot on the south side of an east-west street, so that the rear of the house faces toward the south. The plan provides about 148 m² of floor area, plus a basement.

The design features a spacious formal entrance foyer with a turned staircase and a view through the dining room to a south-facing bay window. The large living room stretches the full width of the house, and includes a decorative masonry alcove with a woodstove. The U-shaped kitchen has a sunny breakfast area adjacent to it with patio doors opening onto a rear deck.

Upstairs the master bedroom includes a full ensuite bathroom. In addition, there are two bedrooms and a study that could be used as a nursery or a dressing room.

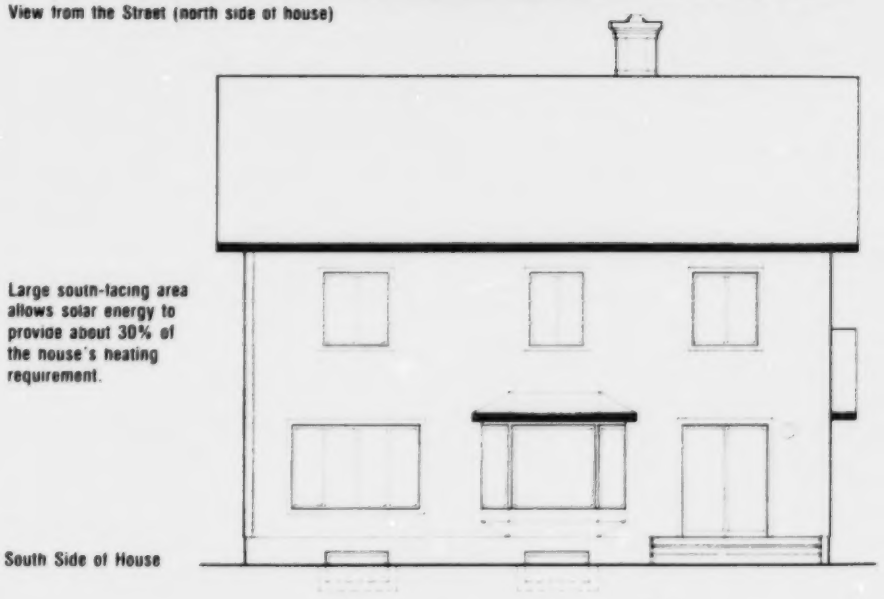
The detailed house plans call for the installation of a heat-recovery ventilation system to ensure a constant supply of fresh air.

Solar Features

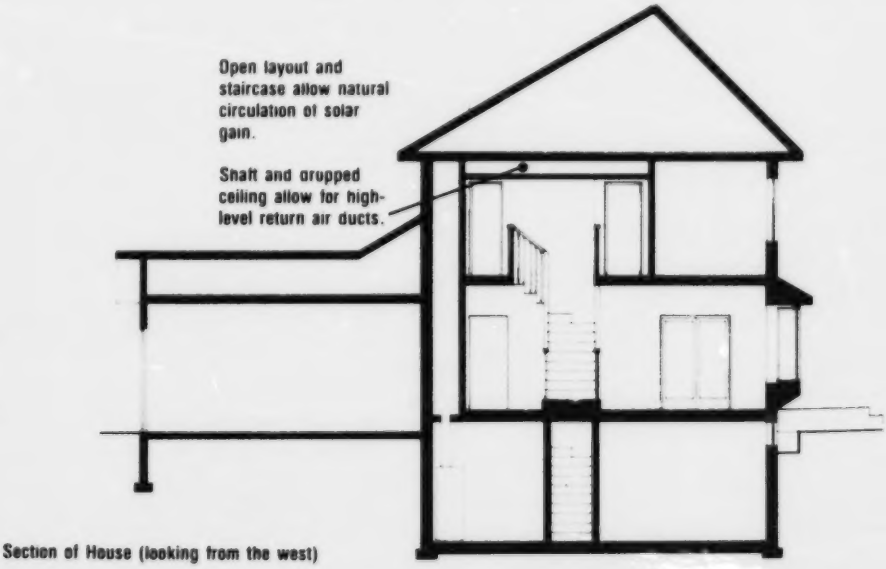
To provide solar gain, the south side of the house features a large glass area that includes the patio doors off the breakfast nook and the bay window off the dining room. In contrast, the north side of the house includes only enough windows to meet the need for daylighting and an attractive exterior appearance for the street side of the house. There are no windows on the west side, and only two small windows on the east.

The ground floor plan is open, providing good natural circulation of solar gain to all major areas. In addition, the open stairwell provides natural circulation to the second floor, as well as providing an attractive design feature. This natural circulation is assisted by the compact house form, which contributes to the overall energy efficiency of the structure. Finally, circulation of solar gain is aided by the forced air heating system with continuous fan operation and high air return.

View from the Street (north side of house)

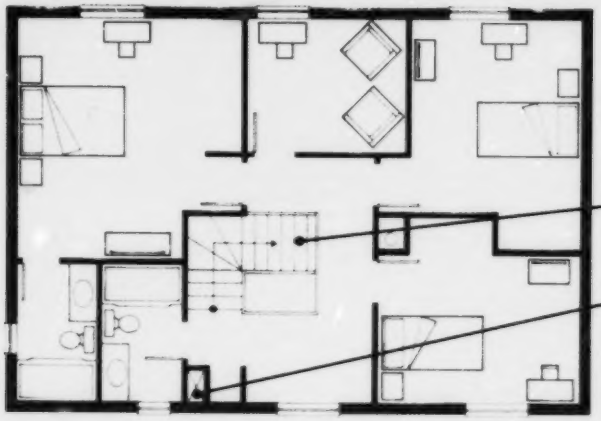


South Side of House


Open layout and staircase allow natural circulation of solar gain.
Shaft and dropped ceiling allow for high-level return air ducts.

Section of House (looking from the west)

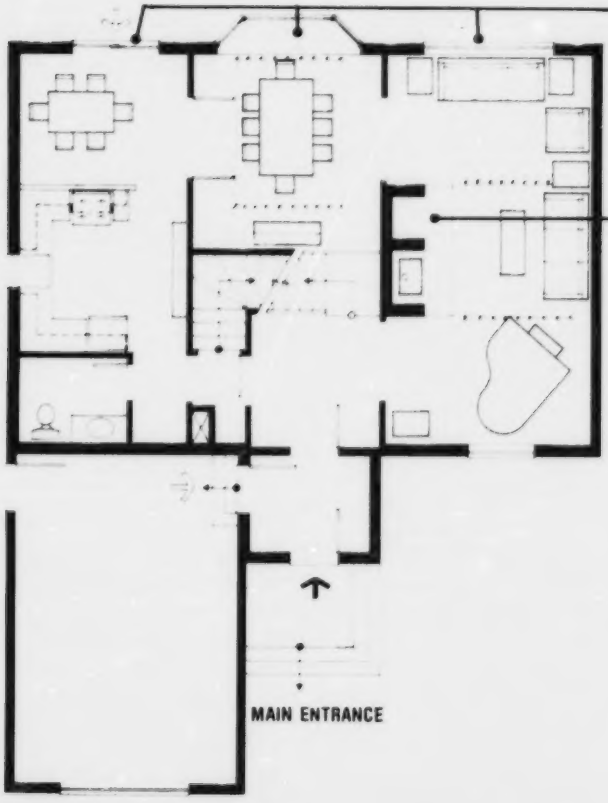
SECOND FLOOR



Stairway is open to the floor below.

Shaft for ductwork.

GROUND FLOOR



Window area is concentrated on the south side of the house.

Living room extends the full depth of the house and features a woodstove to help supplement the passive solar heat.

Open layout provides good air circulation.

S

PERFORMANCE

Location	Annual Energy Consumption for Space Heating (GJ)	Solar Fraction %	Temperature Swing °C
Vancouver	34.5	30.9	6.9
Ottawa	58.1	27.9	1.9
Regina	78.9	38.0	0
Toronto	**58.2**	**28.9**	**3.5**

0 1 2 3 4

METRES

DESIGN THREE

About this Design

The house has been designed with most of the windows located on the south side. Windows on the north have been kept as small as possible while still recognizing the need for adequate light and the desirability of an attractive extreior appearance on the street side. There are only two windows on the east side and none on the west.

The large area of south-facing glass also provides the most striking architectural feature of the home — a two-storey open space featuring a tall glass window. This space rises above the family room and opens onto the second floor den, allowing substantial solar gain and some natural circulation of that gain.

The roof design features a 45° slope deliberately designed to permit installation of a solar collector for hot water or photovoltaic cells at a future date. The recommended landscaping includes deciduous trees to control summer heat gain while maximizing winter gain.

Solar Features

This two-storey house is designed for the south side of an east-west street, so that the rear of the house faces south. The design requires a lot 18 metres wide to accommodate the single-car garage that has been placed at the side.

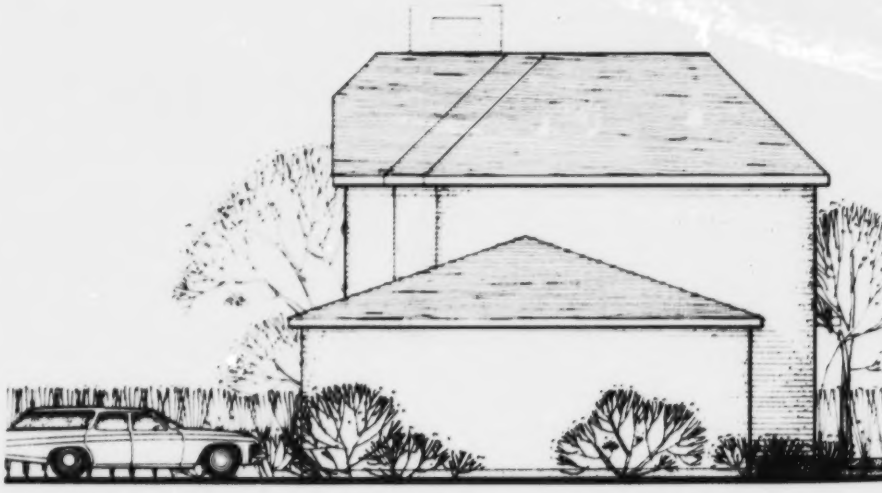
The house has a floor area of about 150 m² on two levels, plus a basement. The design features a centre hall plan with a partially open staircase rising in the centre of the home. The ground floor offers a large kitchen connected to the dining room, and a breakfast nook. The house also features a main-floor family room, which connects to both the breakfast nook and the living room.

Upstairs, the design provides a master bedroom, two other bedrooms and a den that can serve as a fourth bedroom.

Rear View (south side of house)

Roof slope of 45° permits future collection of solar energy through photovoltaic cells or solar collectors for hot water.

Two-storey glass provides sunlight and solar gain to large two-storey space behind.



West Side of House

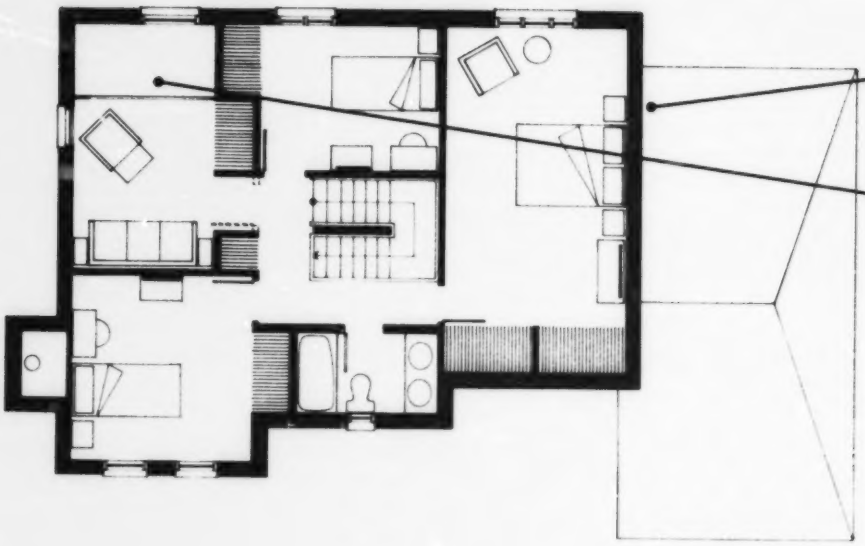
Deciduous trees for summer shading.

PERFORMANCE

[illegible]	[illegible]	[illegible]	[illegible]
Vancouver	33.2	24.3	3.7
Ottawa	57.7	19.1	0.3
Regina	66.5	20.8	0
Windsor	**23.1**	**20.7**	**2.0**

DETACHED HOUSES

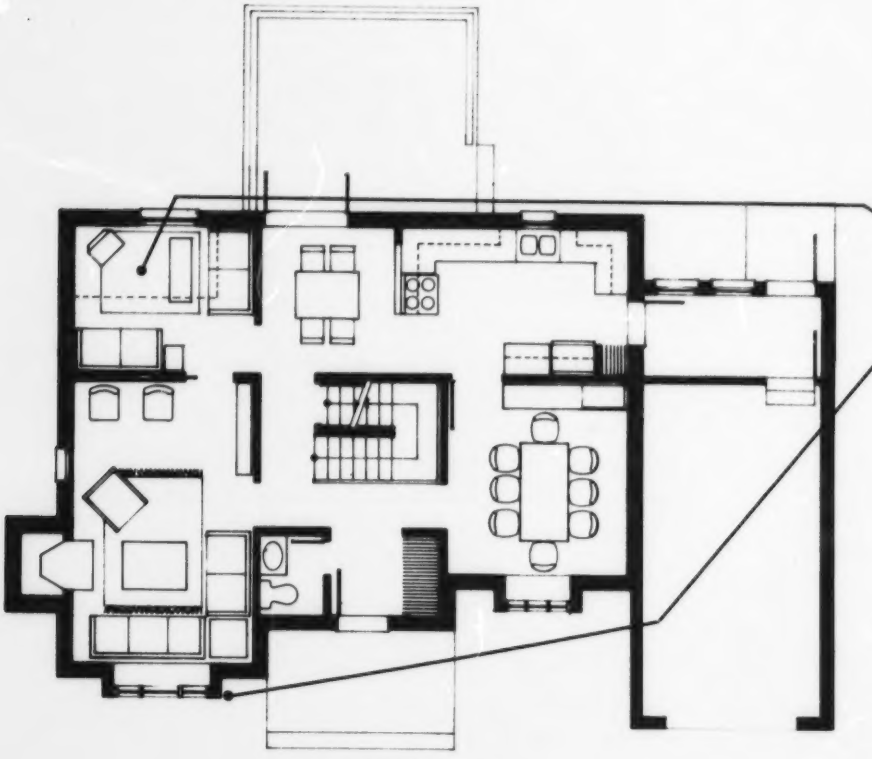
SECOND FLOOR



No windows on west side, to limit heat loss and prevent the possibility of late afternoon overheating.

Open design permits view from den down to family room below and view to the outside through two-storey glass window.

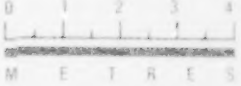
GROUND FLOOR



Two-storey space connects family room to den above.

Bay windows are provided to add interest to both interior and exterior of house.

MAIN ENTRANCE



DESIGN FOUR

About this Design

This two-storey house is designed to be sited on the north side of an east-west street. The house requires a lot 18 metres wide to accommodate the position of the garage on the side of the building.

The house has a total floor area of about 150 m², plus a basement. The design is based on a centre hall plan that provides a living room, dining room, breakfast room, family room, and powder room on the ground floor. In addition, a rear entry area connects to both the garage and a rear yard deck.

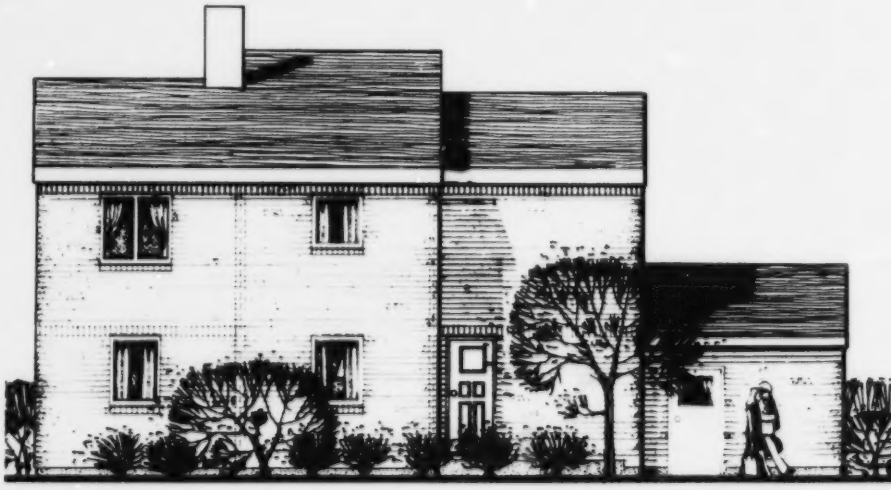
The second floor contains a master bedroom with ensuite bathroom. It also has two other bedrooms and a unique open area that could serve as a play space. At the rear of the play space, an open area looks down into the dining room.

View from the Street (south side of house)

Solar Features

The house design provides for most of the glass area to be on the south side. The east and west sides of the house have no windows and the north side has very few. Even so, all major rooms in the house are provided with natural light.

The south-facing windows include a bay window to provide visual interest. A unique feature is the clerestory windows above the second floor. These provide direct sunlight to the play area and, because of the open space above the dining room, also provide natural light and solar gain to the ground floor dining room.



North Side of House

Shade trees are concentrated in the rear yard to minimize interference with winter solar gain.

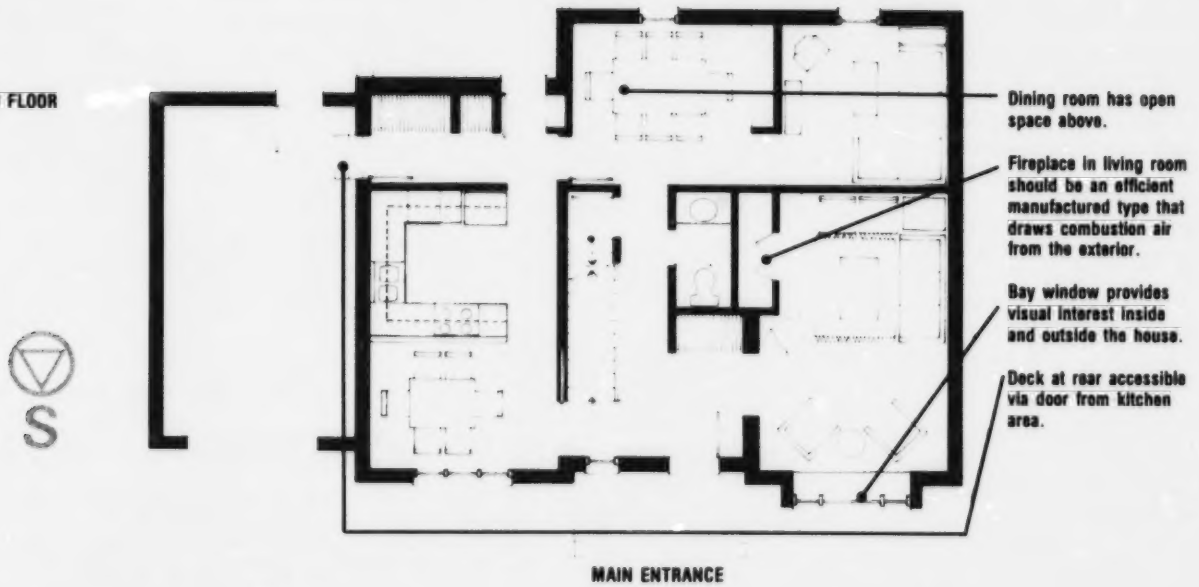
North side of house has few windows.

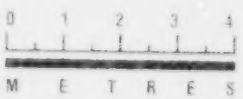
PERFORMANCE

Vancouver	20.7	22.5	3.7
Ottawa	57.0	22.9	0
Regina	78.7	20.2	0
Windsor	**27.8**	**22.3**	**1.2**

SECOND FLOOR

GROUND FLOOR


Dining room has open space above.
Fireplace in living room should be an efficient manufactured type that draws combustion air from the exterior.
Bay window provides visual interest inside and outside the house.
Deck at rear accessible via door from kitchen area.
S
MAIN ENTRANCE



DESIGN FIVE

About this Design

This two-storey house is designed for the north side of an east-west street, so that the southern exposure faces the street. The house offers 135 m² of floor area plus a basement.

The ground floor design effectively separates formal and informal spaces. The living and dining areas are on the west side, while the kitchen, breakfast nook, powder room, family room and utility entrance from the garage are all on the east side of the house. The living room features the fireplace and a vaulted ceiling above.

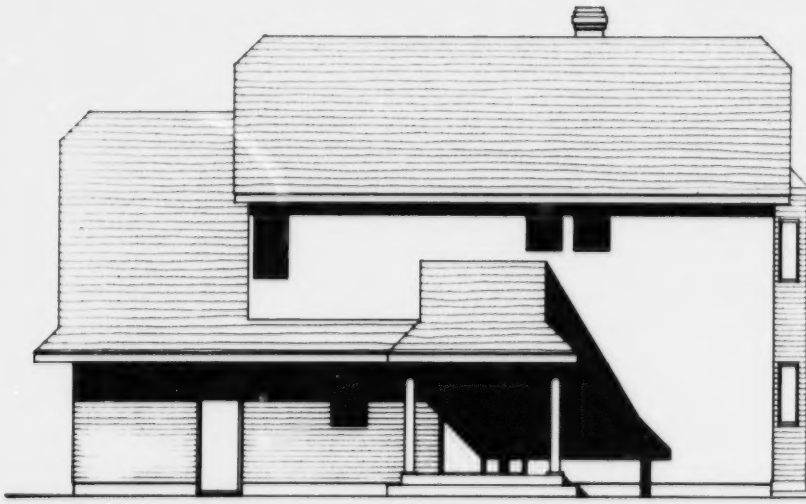
At the second floor level, the living spaces are concentrated at the rear, which allows the roofline to slope down to the first floor level at the front of the house. The design provides a master bedroom with ensuite bath, and two other bedrooms. In addition, there is a small foyer adjacent to the stairwell that can be used as a reading corner or for additional storage.

Solar Features

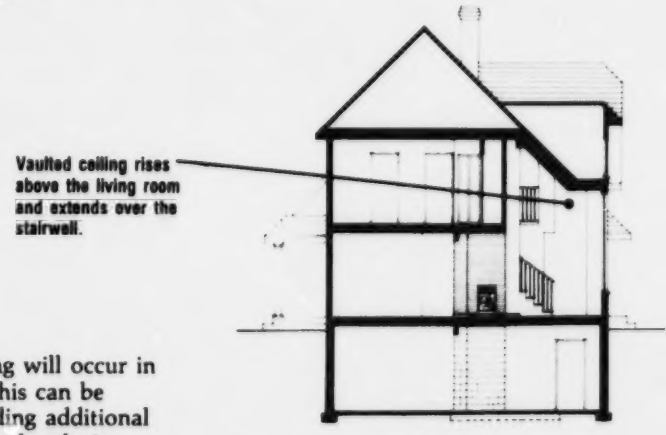
This design has substantial window area clustered on the south side of the house, with limited glass area on the other sides. The most striking solar feature is found in the living room, with its raised and vaulted ceiling. Here the larger glass area that extends up to the second floor level provides large solar gain and good natural air circulation via the open stairwell.

In total, the design provides over 13 m² of glass area. To prevent overheating, the design calls for additional solar storage in materials providing thermal mass. Interior face brick is called for over the east and west walls in the living, dining and family rooms. In addition, face brick is to be incorporated around the fireplace enclosure adjacent to the stairwell. Other wall and ceiling surfaces in the south part of the building are to incorporate a double thickness of drywall. (Although this amount of mass is sufficient to prevent overheating in Regina, the city for which this house was designed, overheating will occur in some other areas. This can be controlled by providing additional mass or by reducing the glazing area.)

View from the Street (south side of house)

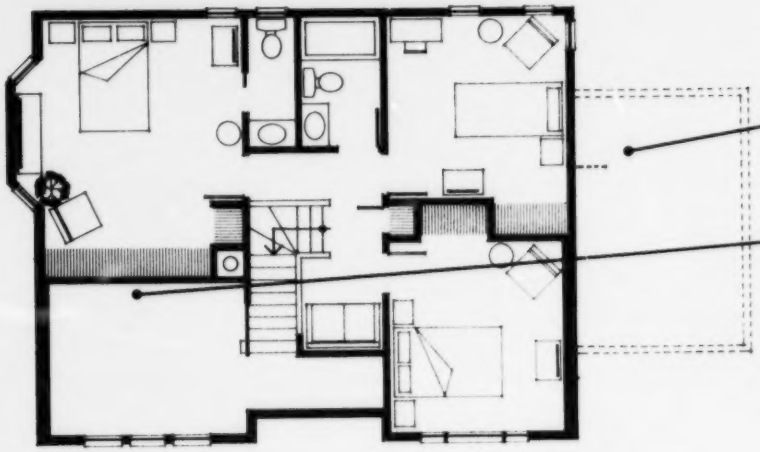


Rear View (north side of house)



Section of House (looking from the west)

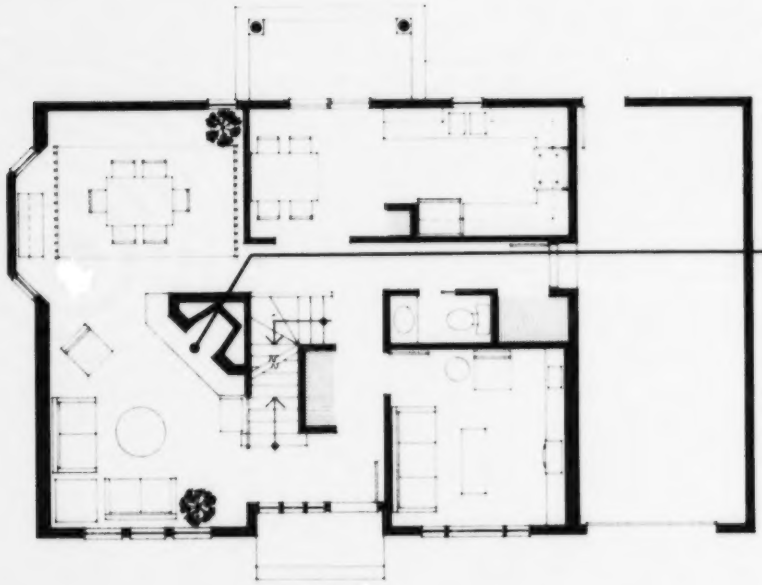
SECOND FLOOR



Attic space adjacent to living area can be used for storage or, possibly, as expanded living area in the future.

The master bedroom could be modified to allow it to open directly to the two-storey open space above the living room. This would improve air flow and provide attractive views from above.

GROUND FLOOR



Fireplace should be the premanufactured type and be provided with combustion air from an exterior source.

Walls in south portion of house are provided with face brick or double-thickness drywall to provide heat storage.

S

MAIN ENTRANCE

PERFORMANCE

Vancouver	31.6	37.2	12.0*
Ottawa	53.5	32.8	7.1*
Regina	**62.7**	**34.8**	**5.8**

*Overheating must be avoided.

0 1 2 3 4

METRES

DESIGN SIX

About this Design

This two-storey house is designed to be located on the south side of an east-west street, so that the rear of the house faces to the south. It is intended for use on a narrow lot only 14 metres wide.

The house provides 148 m² of floor space, plus a basement. The interior design features an open concept, including a full two-storey space above the living room. A bar-style breakfast unit is used as a room divider between the kitchen and dining room; the dining room, in turn, is connected to the living room. The ground floor also provides a family room, powder room and an entry off the garage.

On the second floor, the master bedroom includes an ensuite bathroom and a shuttered opening overlooking the space above the living room. The second floor hall is also open to the living room below. Two other bedrooms and a main bathroom complete the second floor.

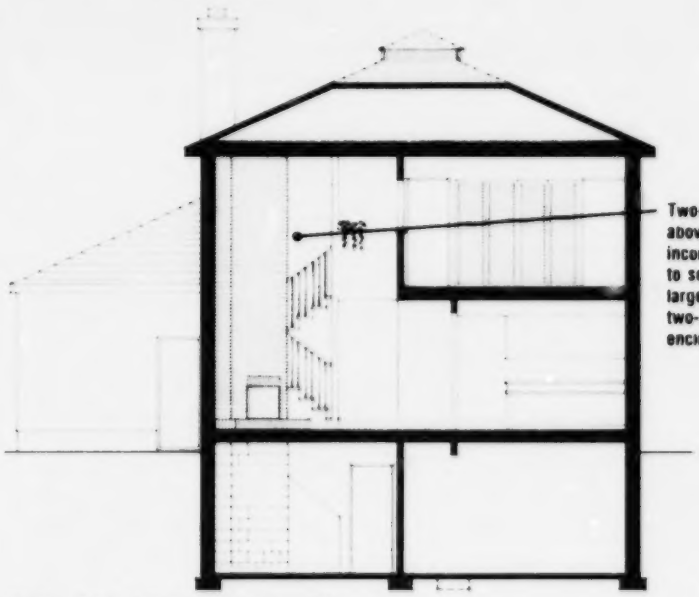
Solar Features

As is usual in a passive solar home, the window area is concentrated on the south side of the house. In spite of the fact that the narrow face of the house is oriented to the south (because of the narrow lot size), enough south-facing glass is provided to collect approximately 30% of the house's heating requirement (depending on location).

To prevent overheating, the house is provided with additional mass in the form of 100 mm concrete block incorporated into the east and west walls and in the exposed two-storey fireplace enclosure. In addition, other interior surfaces in the south zone of the house use double-thickness drywall for added thermal mass.

The house layout encourages natural convection in that the two-storey living room provides for natural air flow from the ground floor to the master bedroom and upstairs hall. In addition, distribution of solar gain through the home is facilitated on the ground floor by the interconnected dining room and kitchen. Even so, natural air flow into the rooms on the north side of the house will be limited.

Rear View (south side of house)



Two-storey open area above living room incorporates staircase to second floor and large thermal mass of two-storey fireplace enclosure and chimney.

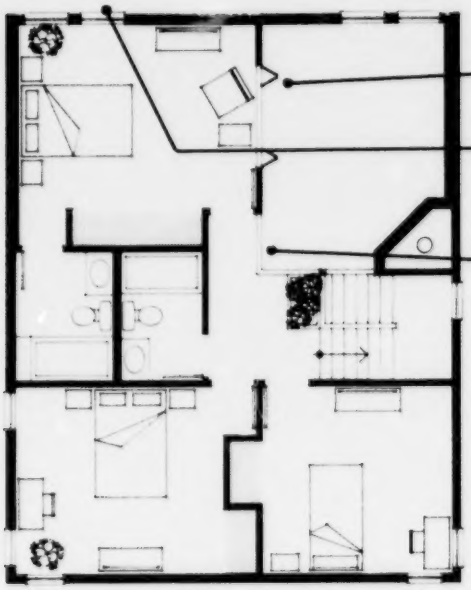
Section of House (looking from the south)

PERFORMANCE

[illegible]	[illegible]	[illegible]	[illegible]
Vancouver	32.2	33.9	7.8*
Ottawa	56.4	28.7	3.8
Regina	**69.6**	**28.6**	**3.0**

* Overheating must be avoided.

SECOND FLOOR



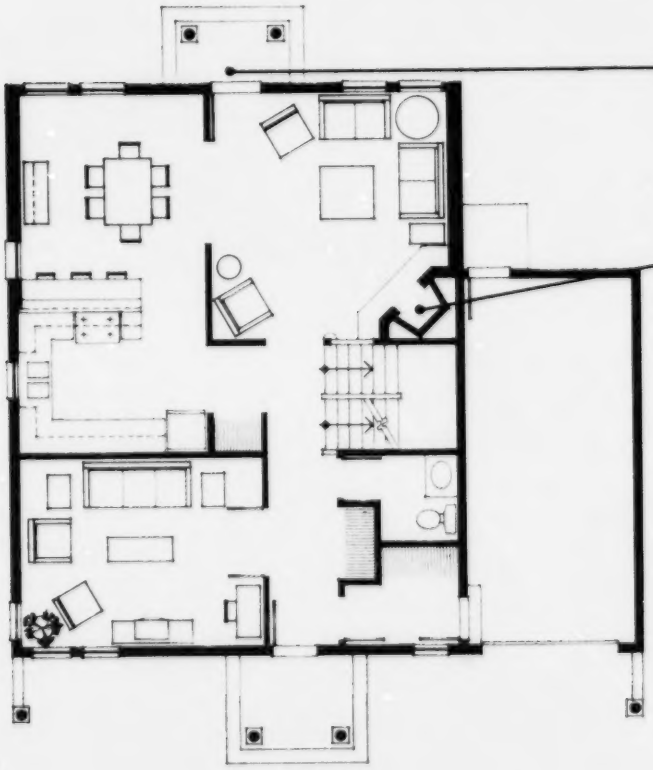
Shutters from master bedroom open into two-storey sun space.

If overheating becomes a problem, retractable canvas awnings could be installed at the second floor level.

Balcony also overlooks two-storey sun space, providing attractive views into the living room and to the outside.

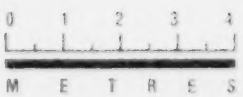
A half-height linen closet is provided below the railing level.

GROUND FLOOR



Rear entrance opens off living room. Alternatively, a sun space or greenhouse could be built in lieu of the back porch.

Fireplace should be premanufactured type drawing exterior combustion air.



DESIGN SEVEN

About this Design

This two-storey house has been designed for the north side of an east-west street, so that the south side of the house faces the street. It is designed for a lot at least 17 metres wide. The house provides 143 m² of space, plus a partial basement. The design is a "side-to-side" split level, which can be built on either a flat or sloping lot.

The most striking feature of the unit is a two-storey open space rising above the ground floor living room and foyer area. The living room also features a fireplace and direct access to the dining room. Completing the upper portion of the floor is a kitchen and a breakfast nook with patio doors opening into the rear yard. The lower level of the ground floor features a family room, powder room and utility area with entrance from the garage.

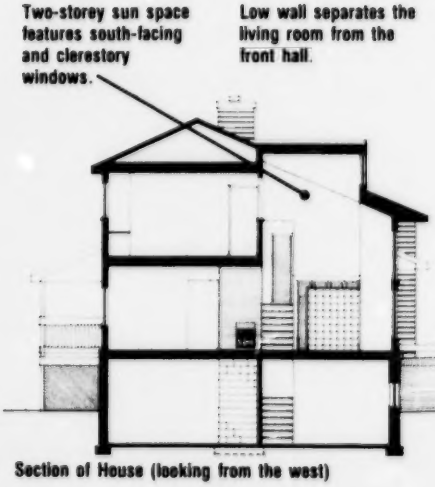
The lower level of the second floor is occupied by the master bedroom complete with walk-in closet and ensuite powder room. The upper level of the second floor includes two bedrooms, one of which overlooks the living room and two-storey sun space. The upper hall also overlooks the two-storey space.

Solar Features

The house is provided with over 10 m² of south-facing glass area, which can provide nearly 40% (depending on location) of the heating requirements. To achieve this level, however, additional thermal mass is required to prevent overheating. Face brick is incorporated as an interior wall finish in the living, dining and family rooms. In addition, the family room is built on a concrete slab on grade, and all other surfaces in the south zone of the house incorporate a double thickness of drywall. (These measures are adequate for Regina, the climate for which this house was designed. In other areas, additional storage or less glazing may be required to prevent overheating.)

View from Street (south side of the house)

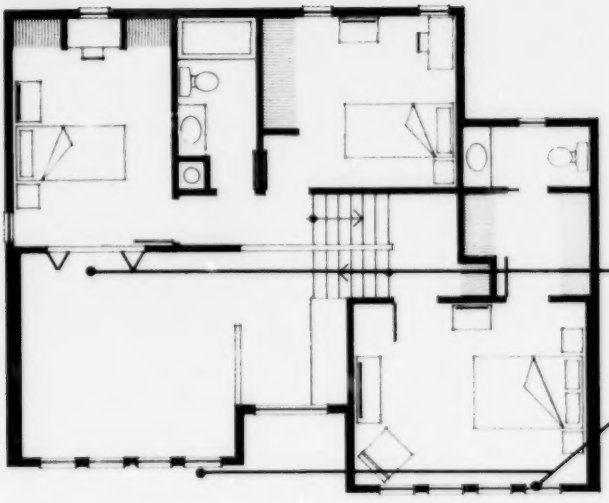
North Side of House


Two-storey sun space features south-facing and clerestory windows.
Low wall separates the living room from the front hall.

Section of House (looking from the west)

Natural air circulation is encouraged by the large two-storey space, which is connected to the rear of the house at the second-storey level. In addition, the open layout of the ground floor will encourage natural heat circulation. Finally, natural circulation is boosted by the use of a forced air heating system.

SECOND FLOOR

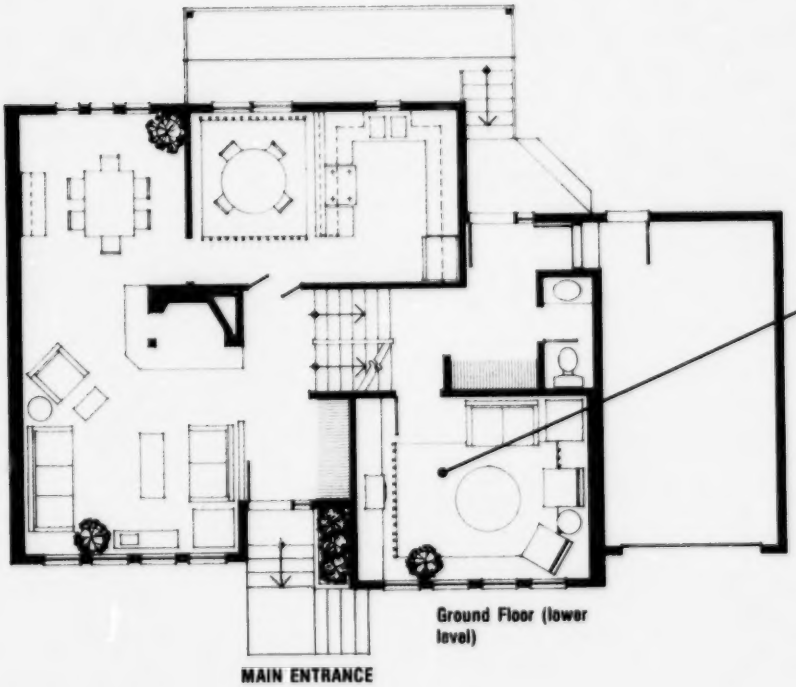


Second Floor (lower level)

Bedroom and hallway overlook two-storey sun space. Shutters can provide privacy in the bedroom when required.

Retractable canvas awnings or other shading devices can provide additional shading if overheating becomes a problem.

GROUND FLOOR



Ground Floor (lower level)

MAIN ENTRANCE

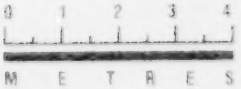
Open layout allows good air circulation.

Family room is built as a slab on grade to provide storage mass.

A forced-air system is used to prevent overheating.

Vancouver	38.3	40.2	15.0*
Ottawa	64.0	35.3	10.4*
Regina	**76.7**	**38.4**	**5.0**

* Overheating must be avoided.



DESIGN EIGHT

About this Design

This two-storey house is designed to be located on the south side of an east-west street, so that the rear of the house faces towards the south. Although the long side of the house is oriented towards the south, the design is compact enough to allow construction on a lot only 15 metres wide.

The design provides a floor area of 139 m² plus basement. The ground floor features a sunny living room with bay windows and a fireplace. The kitchen is large enough to provide a breakfast area, and is bright because of the large window area and patio doors opening onto a rear deck. A dining, room, family room and powder room are also located on the ground floor.

The second floor features a master bedroom with ensuite bath, two additional bedrooms and the main bathroom. The stairway between floors is open so that the short hallway on the second floor overlooks the front entry.

View from the Street (north side of house)

Solar Features

The design provides over 15 m² of south-facing glass area. By placing hallways, stairways and utility areas on the north side, the design ensures that all main rooms receive direct solar gain, except for the dining room and one second floor bedroom. Additional thermal mass is provided by the use of brick facing on the east and north walls in the living room (including the fireplace) and on the west and south walls in the family room. Additional mass is provided in the south-facing rooms by the use of double-thickness drywall on the ceilings and on the remaining walls.

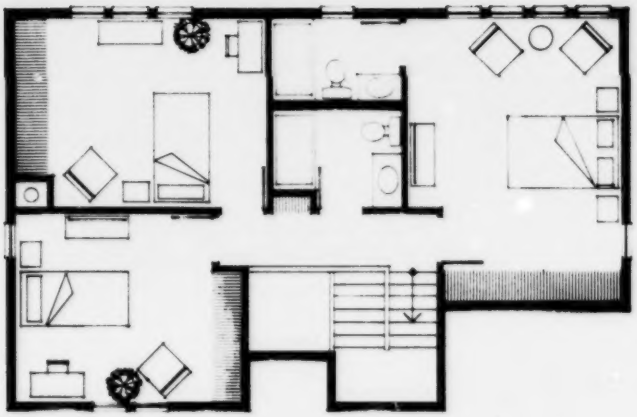
South Side of House

PERFORMANCE

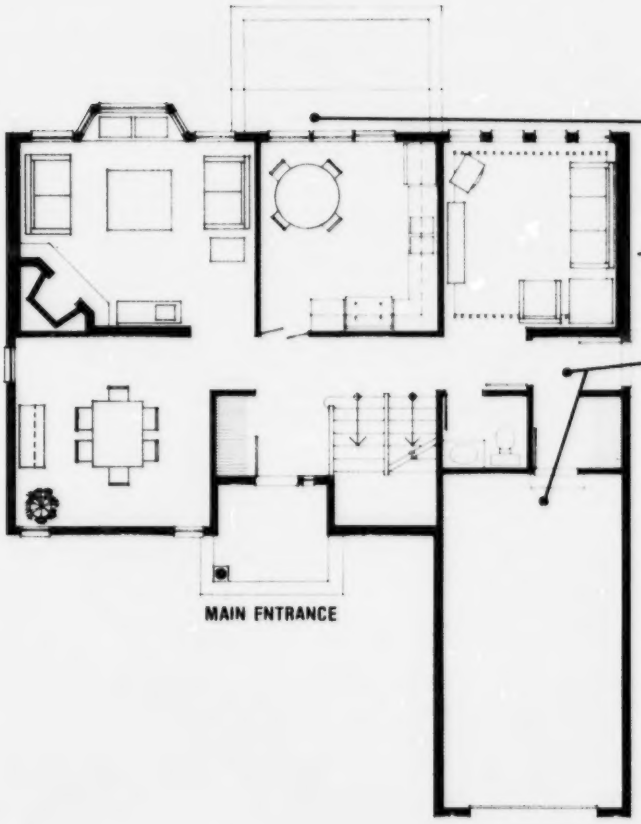
Location	Auxiliary Energy Required (GJ)	Heating Load (GJ)	Overheating (%)
Vancouver	31.5	37.7	11.2*
Ottawa	51.5	33.6	6.7
Regina	**63.9**	**32.9**	**5.1**

* Overheating must be avoided.

SECOND FLOOR



GROUND FLOOR

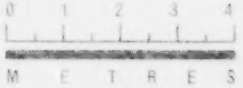


Rear deck could be converted into a sun space built over a slab on grade for heat storage.

Thickened walls provide thermal mass for heat storage.

Utility entrance connects to both the garage and the outdoors.

Design concentrates living spaces on the south side of the house.



DESIGN NINE

About this Design

This two-storey house is designed to be located on the south side of an east-west street, so that the rear of the house faces south. The unit is designed to fit on a lot 15 metres wide, but a wider lot would be beneficial since the design features a deck at the side of the house.

The house provides 142 m² of living space plus a basement. On the ground floor, the dining and living rooms are connected in an open plan focussing on a free-standing central fireplace. Access to the outside deck is from the living room. The dining room is open above, providing a striking two-storey space. The kitchen and family room are part of a single open space, separated by a bar-style breakfast area and by a step down into the sunken family room.

On the upper level, the hallway and one of the bedrooms overlook the dining room, providing a view into the two-storey space. The main bedroom, the master bedroom with ensuite bath and walk-in closet, and a third bedroom are also located on the second floor.

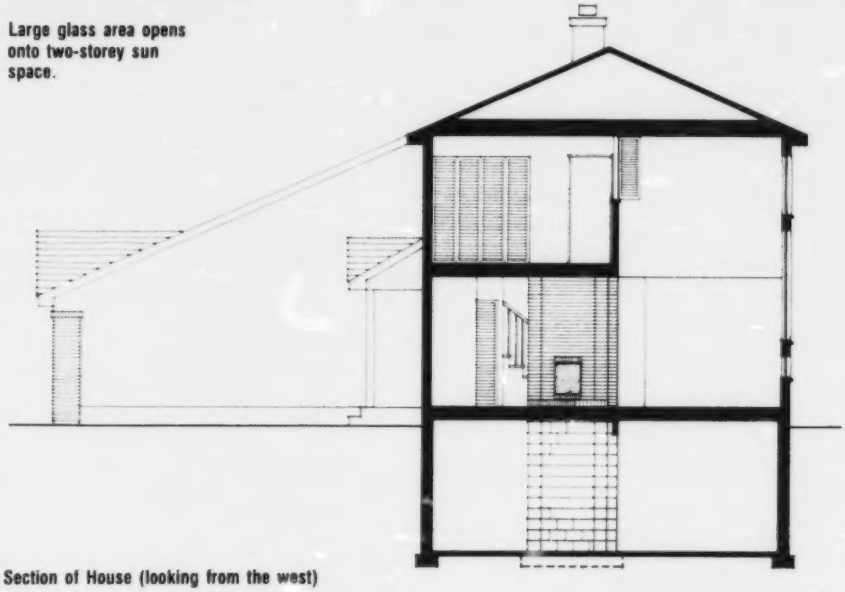
Solar Features

The design provides over 19 m² of south-facing glass area, but very little glass area on the other sides of the house. The result is that solar gain can make about a 40% contribution to the heating requirements (depending on location). To prevent overheating, mass has been provided in the form of face brick surrounding the fireplace, and on the north wall within the kitchen-family room combination. All other wall and ceiling surfaces within the south part of the house are treated with double-thickness drywall.

The single most striking feature in this home — the two-storey sun space above the dining room — provides a large part of the solar gain, and also provides for natural circulation of heat. The shallow depth of the house, the open layout, and the careful positioning of living areas on the south ensure that all the main rooms receive solar gain.

Rear View (south side of house)

Large glass area opens onto two-storey sun space.



Section of House (looking from the west)

Second-storey bedroom overlooks two-storey sun space. The open exposure from the bedroom can be closed off with shutters for privacy.

PERFORMANCE

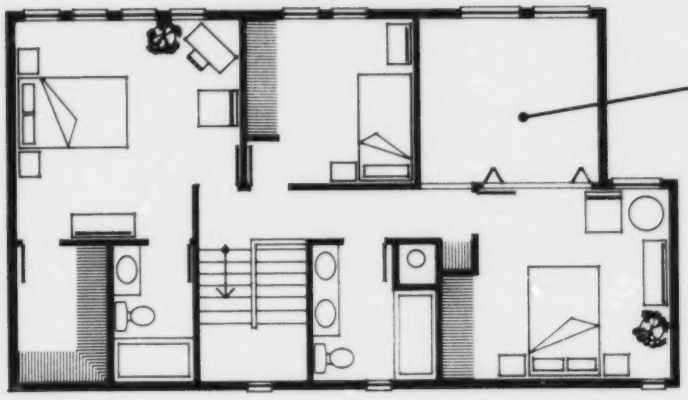
Vancouver	31.4	41.2	13.3*
Ottawa	54.5	36.4	10.1*
Regina	**61.8**	**41.1**	**5.0**

* Overheating must be avoided.

The design calls for the use of a forced-air heating system to prevent overheating. In locations other than the one for which this house was designed, additional storage or reduced glass area will be necessary.

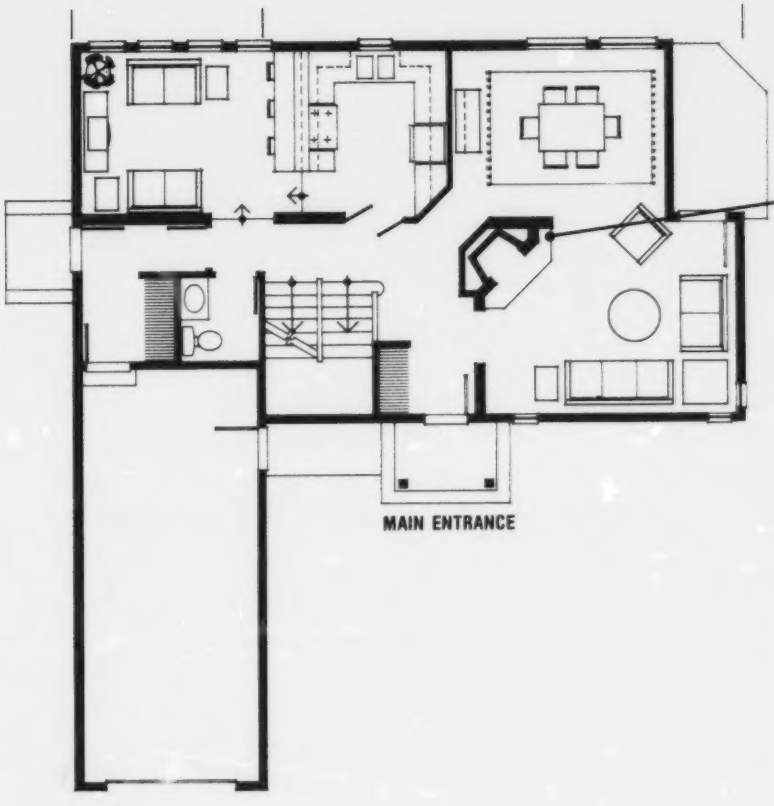
A forced air system is used to avoid overheating.

SECOND FLOOR

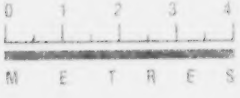


Open area above dining room provides striking two-storey space that also provides for natural circulation of air.

GROUND FLOOR



The fireplace is a focal point of the living and dining areas. The face brick surrounding it provides important thermal storage.



DESIGN TEN

About this Design

This two-storey house is designed to be located on the north side of an east-west street, so that the street side of the house faces south. The house is designed for a lot 15 metres wide. It provides 142 m² of floor area, plus a basement.

The design features a modified central hall concept, with utility areas at the rear of the house (the north side) and living areas at the front.

The most striking feature of the design is a two-storey open space above the living room. Because this open space is centrally located, at the second floor level it opens onto the central hall, the master bedroom, and a second bedroom. Thus, most areas on the second floor have a pleasing view into the living room and to the outside.

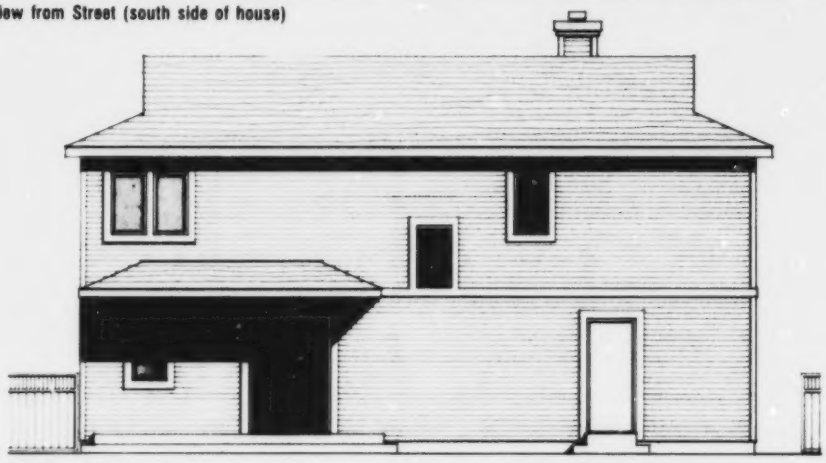
On the ground floor, the dining room is also positioned against the south wall. On the north is the kitchen and a small breakfast area, with patio doors opening to a small rear deck. The staircase and powder room are also located at the rear, adjacent to an entrance from the garage.

Solar Features

The south-facing wall of this house design includes over 15 m² of glass area, enough to provide about 30% of the house' heating requirements (depending on location).

To prevent overheating, extra thermal mass is provided. The most striking area of mass is found in the fireplace and in the chimney, which extends a full two storeys through the open space above the living room. The mass is formed of 100 mm concrete blocks covered with a stucco-like interior finish. The same materials are also used on the north and west walls of the living room and on the north wall of the family room. All remaining surfaces in the south part of the house have a double layer of drywall interior finish to provide additional mass.

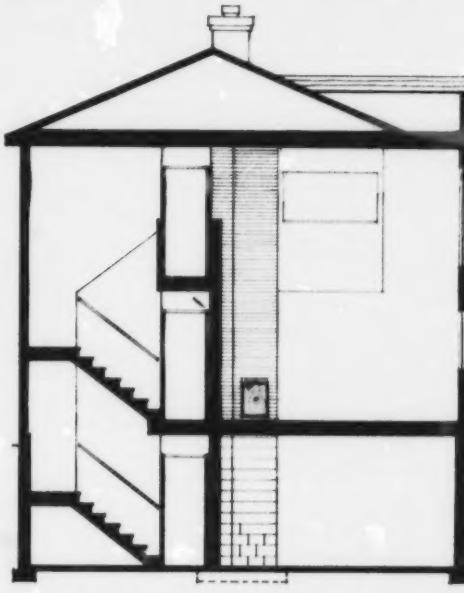
View from Street (south side of house)



North Side of House

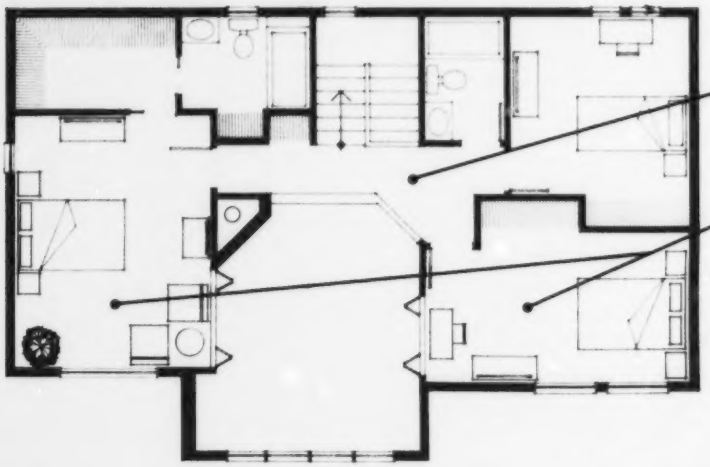
The two-storey atrium-like space, opening as it does onto three distinct areas on the second floor, will help natural air circulation (particularly when doors are left open). The open stairway at the rear will also assist natural air circulation. Mechanical circulation (fans) or the forced air heating system will further improve heat distribution.

During summer, the south-facing window areas should be shaded with blinds or retractable canvas awnings to control potential overheating.



Section of House (looking from the west)

SECOND FLOOR

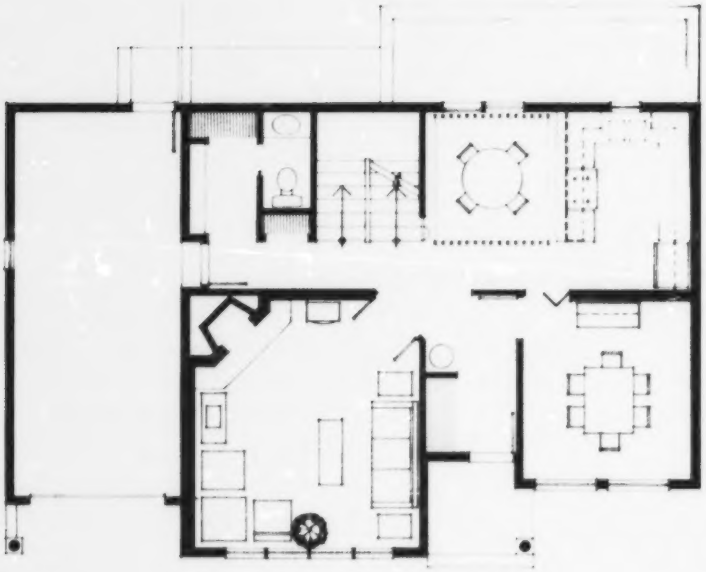


Upper hallway creates interesting bridge effect between atrium and stairwell.

Bedrooms overlook atrium, with shutters to provide privacy when required.

Some walls incorporate concrete block and stucco finish to provide additional thermal mass. Other walls in south area use double drywall.

GROUND FLOOR



Garage is located beneath master bedroom.

MAIN ENTRANCE

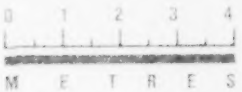
Openings from second-storey bedrooms and hallway overlooking the two-storey sun space create an atrium-like effect.

Fireplace enclosure and chimney extend two full storeys high, providing visual appeal and heat storage. The atrium at front and stairwell at rear provide a natural path for air circulation.

PERFORMANCE

Vancouver	34.0	35.0	11.3*
Ottawa	59.6	38.9	7.0
Regina	**69.8**	**31.6**	**6.1**

*Overheating must be avoided



DESIGN ELEVEN

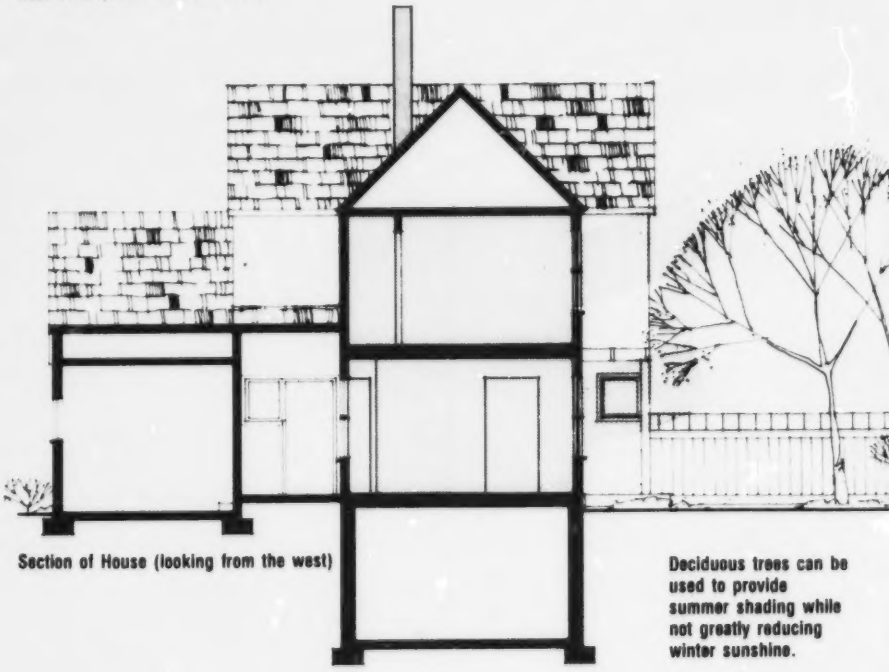
About this Design

This two-storey semi-detached house is designed to be built on the south side of an east-west street, so that the rear of the house faces south. The house is designed for a lot 25 metres wide (for both units). The garages are located at the front of the house; however, to allow the house to be set reasonably close to the street and to make the best use of backyard space, the garages have been turned parallel to the street.

On the ground floor, each unit contains a living room with fireplace and patio doors that open onto a rear deck. There is a separate dining room with easy connection to both the kitchen and the living room. The kitchen has sufficient space for a breakfast area. Upstairs, there are three bedrooms, one bathroom and a linen closet. In total, each of the two units provides 121 m² of space plus a basement.

This design lends itself to a variety of exterior treatments. Apart from changes to the roof pitch and type or changes to the type of siding, consideration could be given to changing the layout of the garages. One could be turned to face the street and the other to run parallel to the street; a curved driveway would be required.

Rear View (south side of house)



Section of House (looking from the west)

Deciduous trees can be used to provide summer shading while not greatly reducing winter sunshine.

All parts of the west wing of the house receive direct solar gain.

Solar Features

The house design is long and thin. This means that heat loss will be greater than it would be with a more compact structure. On the other hand, this design allows direct solar gain to all major living areas of the house. The area of south-facing glass is considerable, providing about 25 to 30% of the heating requirements of the house (depending on location).

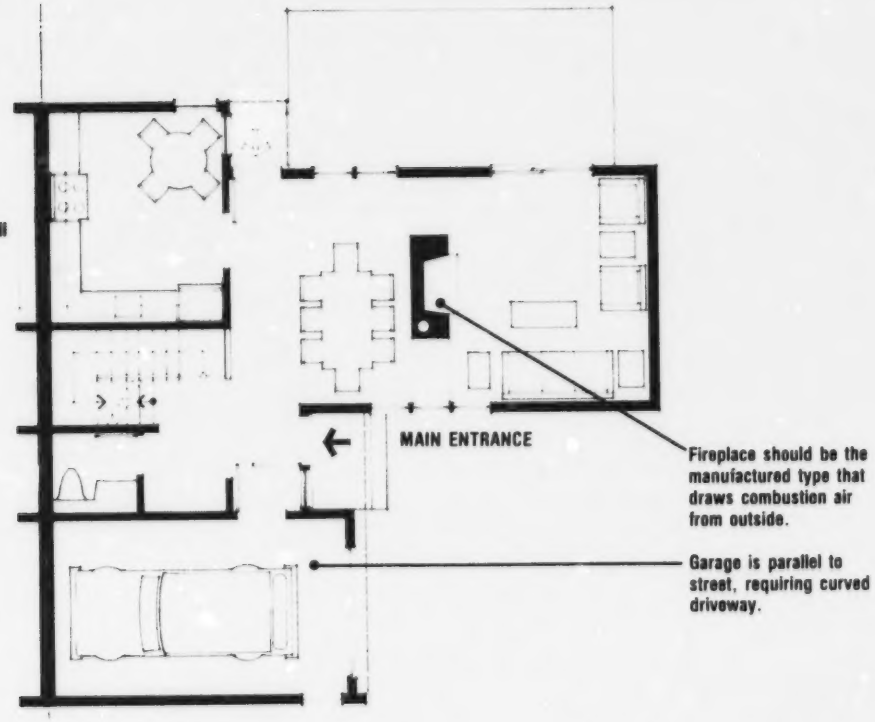
If additional south-facing glass is desired, thermal mass should be introduced into the walls and floors in the living, dining, and kitchen areas to control temperature swing. One possibility for increasing the south-facing glass area lends itself particularly to a sloped site (sloping away to the north). In such a case, larger windows could be added to the basement wall to provide solar gain and, with proper design and insulation, the concrete in the basement could be used for storage. A similar option can be pursued on a flat site if the grade and the height of the foundation are adjusted properly.

SEMI-DETACHED HOUSES

SECOND FLOOR

Party Wall
Fourth bedroom can be provided over the garage and connected to the rest of the upstairs through conversion of the linen closet into a corridor.

GROUND FLOOR


Party Wall
MAIN ENTRANCE
Fireplace should be the manufactured type that draws combustion air from outside.
Garage is parallel to street, requiring curved driveway.

S

PERFORMANCE

Vancouver	**25.1**	**30.2**	**5.3**
Ottawa	42.7	26.1	1.5
Regina	54.0	25.8	0

0 1 2 3 4
METRES

DESIGN TWELVE

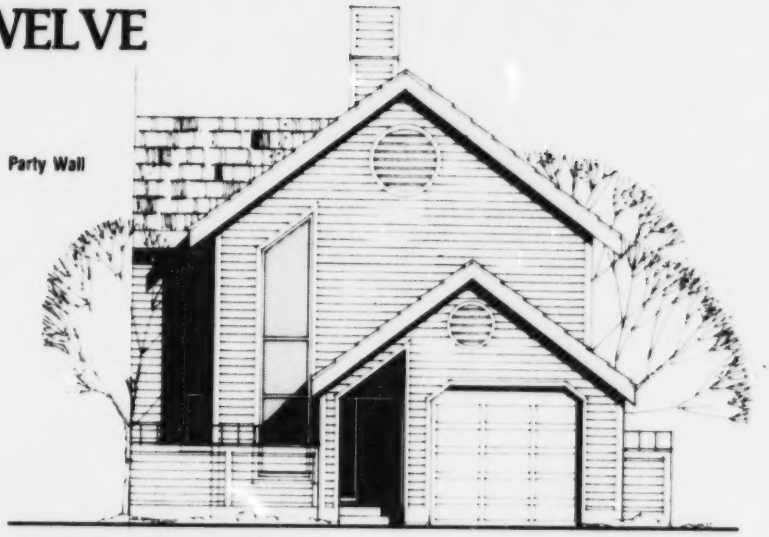
About this Design

This two-storey semi-detached unit is designed to be built on the south side of an east-west street, so that the rear of the house faces south. The house is designed for a narrow lot, such as an older "infill" lot commonly found close to the centre of established cities.

At the front of the house, a courtyard and covered walkway lead to the front door. With careful landscaping and skylights in the roof of the covered walkway, an attractive entrance is presented to visitors.

The interior of the house provides 122 (or 129) m^2 of floor space, plus a basement. On the ground floor, there is a living room with fireplace, and patio doors onto a rear deck. The kitchen is also provided with a door onto the rear deck, and is large enough to include a small breakfast area. The dining room is adjacent to the kitchen, and is built with a two-storey open space above it.

On the second floor, two of the bedrooms overlook the dining room, providing a pleasing view to the ground floor and to the outside. The master bedroom, at the front of the house, includes a small dressing alcove and a door into the main bathroom (which also opens into the hall).



View from Street (north side of house)

Rear View (south side of house)

Strong gable ends and steeply pitched roof provide an exterior appearance more appropriate in an urban setting than a suburban subdivision.

Deciduous trees can be used to provide summertime shading.

Solar Features

The south-facing glass in this design is sufficient to provide about 30% of the house's heating requirement (depending on location). On the main floor, all living areas are provided with south-facing windows, although the living room windows will be shaded in the morning in the case of the unit illustrated here (and in the afternoon in the case of the matching unit that forms the other half of this semi-detached house).

Upstairs, only the master bedroom does not receive direct sunlight, and one of the south-facing bedrooms will be shaded in the same way as the living room below. The open two-storey space above the dining room will provide for some natural circulation of the solar gain. This should be enhanced by a two-speed fan installed on the forced air furnace.

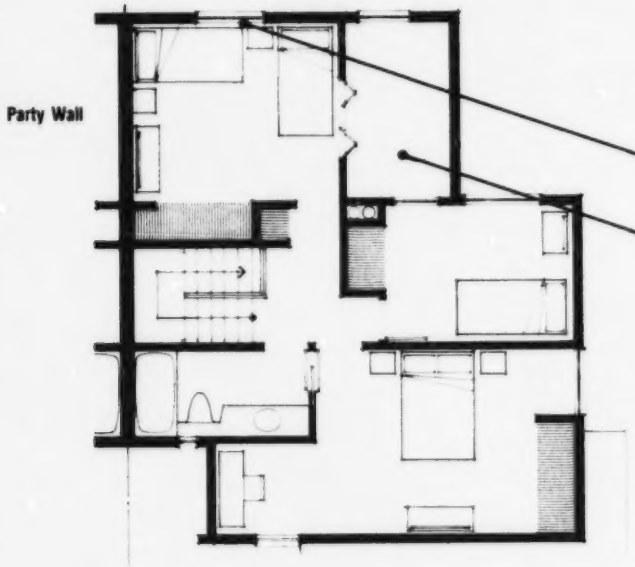
A forced-air system is used to prevent overheating.

PERFORMANCE

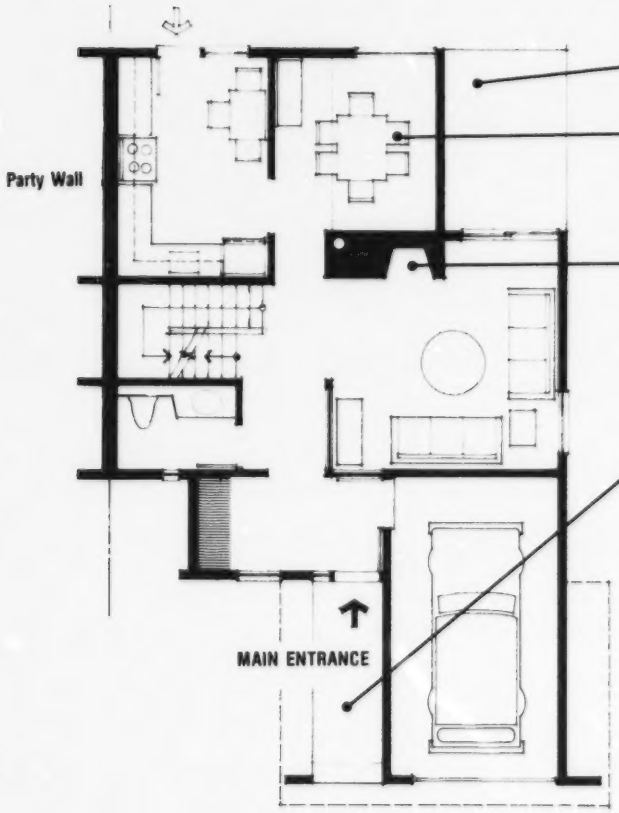
[illegible]	[illegible]	[illegible]	[illegible]
Vancouver	**23.9**	**38.9**	**5.0**
Ottawa	43.9	30.1	5.8
Regina	56.3	29.2	2.7

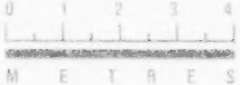
SEMI-DETACHED HOUSES

SECOND FLOOR


Party Wall
Window would be shaded from the morning sun.
Open space looking down over dining room. Shutters can be provided in the opening if privacy is desired.

GROUND FLOOR


Party Wall
Design provides for enclosed courtyard in this area.
Two-storey space above dining room provides striking visual appeal and circulation of solar gain.
Fireplace should be manufactured type that uses exterior combustion air.
Covered walkway leads to main entrance.
MAIN ENTRANCE



DESIGN THIRTEEN

About this Design

This two-storey semi-detached home is designed for the north side of an east-west street, so that the front of the house faces south. It has a conventional design, with a square plan, and a garage on the side. The cost of construction should be moderate.

The house provides 129 m² of living area, plus a basement. Note that open and convenient access to the basement is provided from the kitchen, allowing for the possible future development of the basement.

The ground floor consists of a large L-shaped living room-dining room combination. French doors open off the living room onto a large sun deck at the front of the house. At the rear of the house, the kitchen-breakfast nook is located adjacent to the dining room, and a pass-through is provided between the kitchen and the dining room. A door from the breakfast nook gives access to the rear yard. There is also a pantry and a powder room.

On the upper level, there are three bedrooms and a single bathroom. The master bedroom has private access to the bathroom through a walk-in closet.

Solar Features

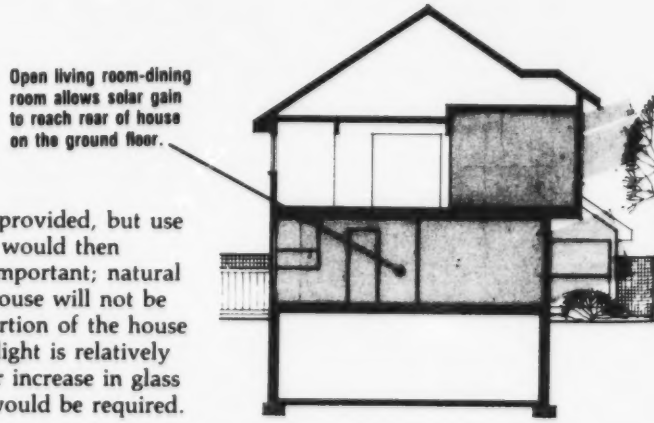
The south-facing glass area on the street side provides solar gain equivalent to about 25% of the house's heating requirements (depending on location). On the ground floor, the garage takes up some of the southern exposure, but because the living room-dining room extends the full depth of the house, a reasonable portion of the living area receives direct solar gain.

On the second floor, two of the three bedrooms receive direct solar gain. The large bay window in the master bedroom, apart from its visual interest, also provides summer shading to the large glass area in the living room below.

If a solar contribution of above 25% is required, additional south-facing glass can be provided, but use of a circulating fan would then become extremely important; natural circulation in this house will not be strong, since the portion of the house receiving direct sunlight is relatively small. With a major increase in glass area, heat storage would be required.

View from Street (south side of house)

North Side of House



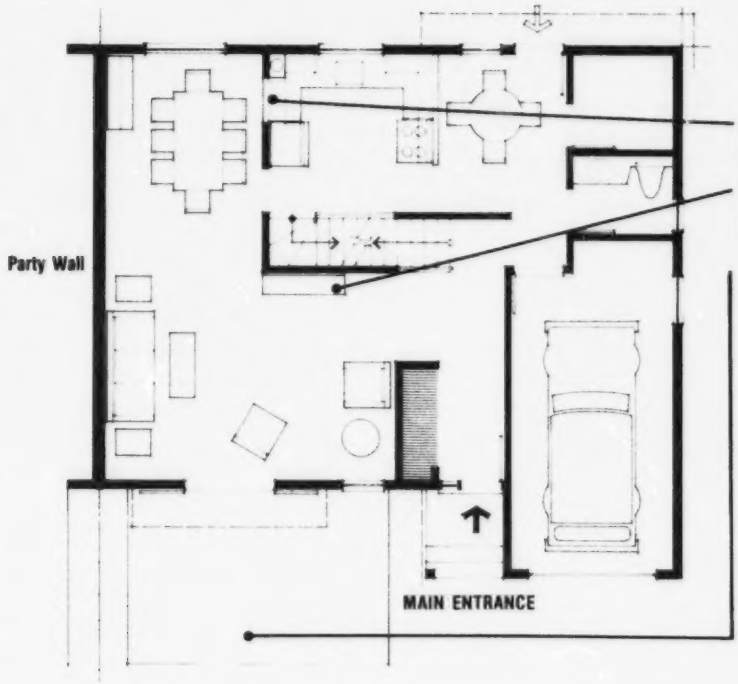
Section of House (looking from the west)

SEMI-DETACHED HOUSES

SECOND FLOOR

Walk-through closet provides direct access to bathroom and has an additional basin.

GROUND FLOOR



Pass-through from kitchen to dining room.

A fireplace could be provided adjacent to the stair.

Sun deck opens off living room.

S

PERFORMANCE

Vancouver	27.9	26.5	5.6
Ottawa	46.3	23.8	1.8
Regina	57.5	25.5	0

0 1 2 3 4

METRES

DESIGN FOURTEEN

About this Design

This two-storey semi-detached house is designed for the north side of an east-west street, so that the front of the house faces south. The design provides 139 m² of floor area plus a basement.

The ground floor of the house includes a living room with a fireplace, a dining room with vaulted ceiling, a kitchen with breakfast area, a powder room, and a pantry.

Upstairs, the master bedroom has an ensuite bathroom and opens onto the vaulted ceiling space above the dining room. There are two more bedrooms and a main bathroom.

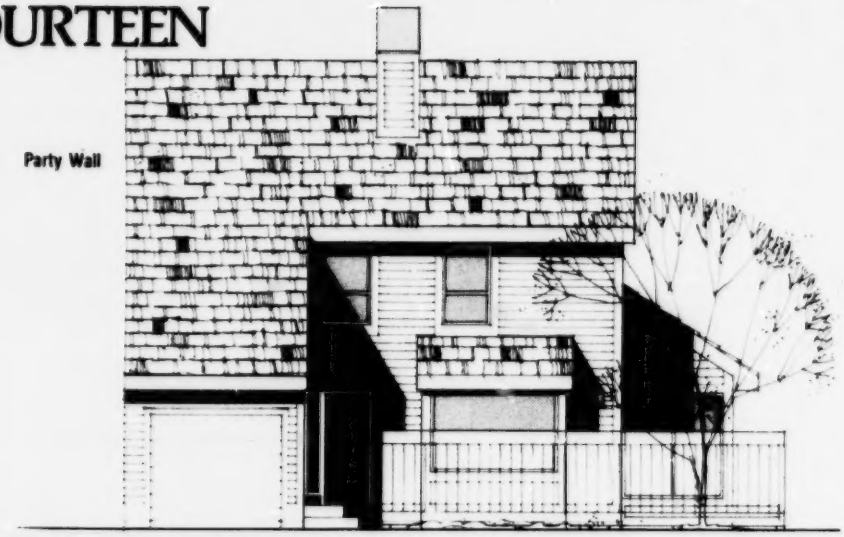
The position of the garage and the use of the fencing around the front yard can provide privacy for the entrance and for a front yard deck that opens off the dining room.

Solar Features

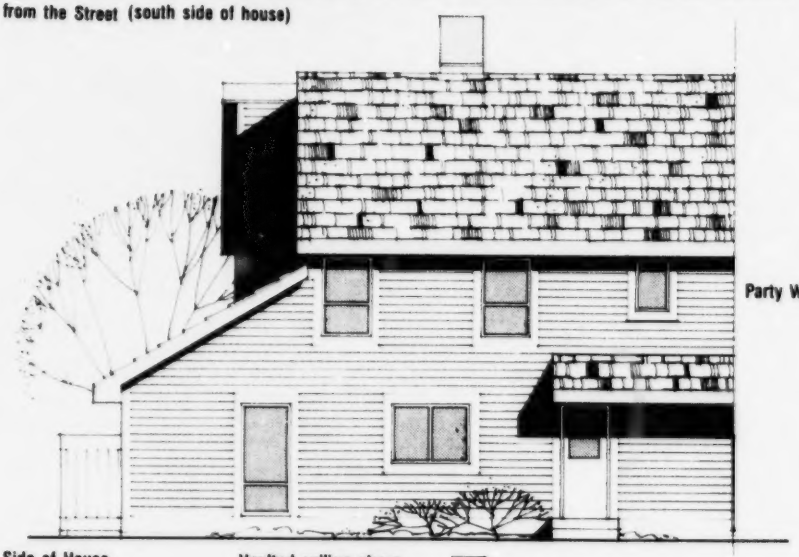
The south-facing glass area is sufficient to provide 20 to 25% of the heating load of the home, depending on location. The position of the garage and the width of the southern exposure, however, limits the areas of the house that receive direct solar gain. On the ground floor, only the living room is at the front of the house. The dining room, at the rear, also receives direct solar gain through a set of patio doors. On the second floor, two bedrooms receive direct sunlight; the master bedroom, bathrooms, and stairs do not.

The staggered house design shades some of the glass area. The eastern-most unit will experience reduced solar gain in the afternoon when the sun is in the western sky; the other unit will experience reduced solar gain in the morning (when the sun can be most beneficial in helping bring the house up to daytime temperatures).

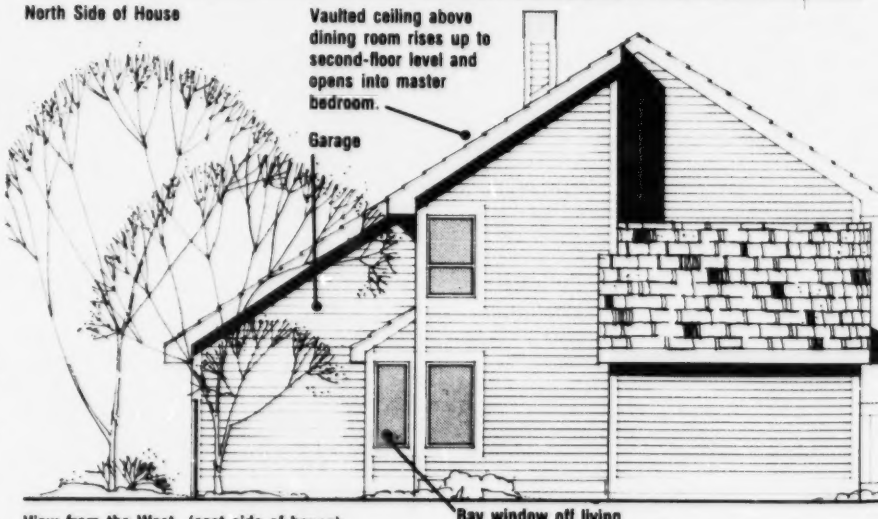
The vaulted ceiling over the dining room and its connection to the master bedroom will help natural air circulation. A forced air heating system and carefully positioned return air ducts provide additional circulation.



View from the Street (south side of house)



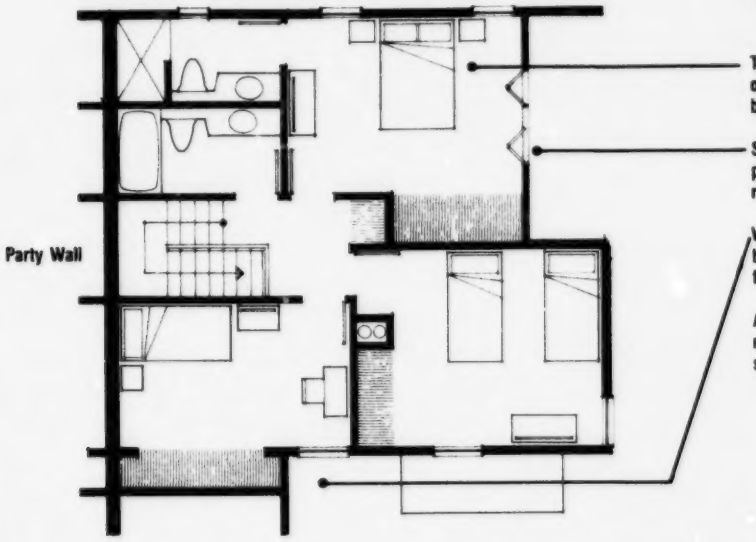
North Side of House


Vaulted ceiling above dining room rises up to second-floor level and opens into master bedroom.
Garage
Bay window off living room.

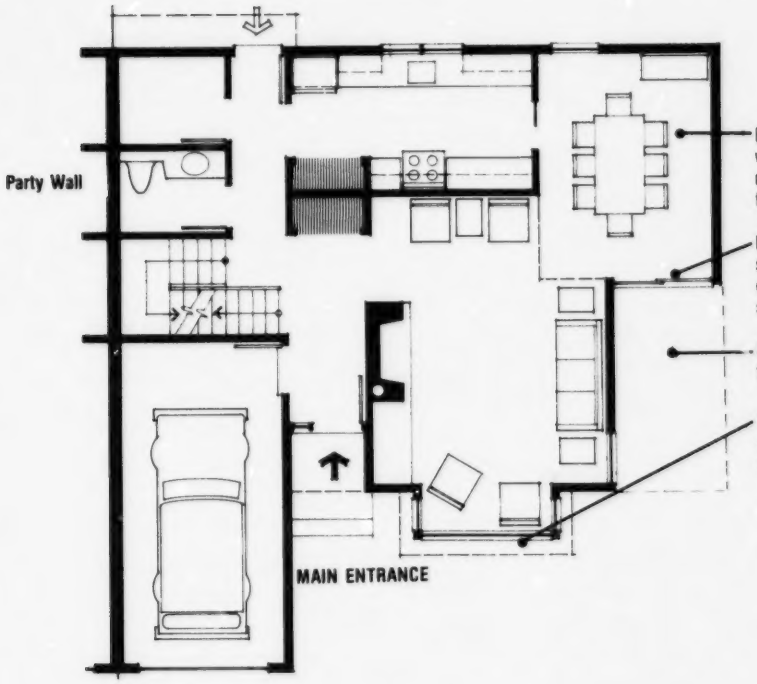
View from the West (east side of house)

SEMI-DETACHED HOUSES

SECOND FLOOR


Party Wall
The master bedroom overlooks dining area below.
Shutters can be used to provide privacy as required.
Window will be shaded by roofing over garage for part of the day.
Attached unit has reversed version of same floor plan.

GROUND FLOOR


Party Wall
Dining room has vaulted ceiling above, rising to the second floor level.
Patio doors will be shaded for part of the day by the house structure.
Deck accessible from the dining room.
Bay window will be shaded for part of the day by the garage.
MAIN ENTRANCE

S

PERFORMANCE

Vancouver	**33.4**	**24.8**	**4.2**
Ottawa	55.6	23.3	1.8
Regina	70.2	23.1	0

0 1 2 3 4

METRES

DESIGN FIFTEEN

About this Design

This two-storey semi-detached house is designed for the north side of an east-west street, so that the front of the house faces south. The house provides 144 m² of floor space, plus a basement.

The ground floor offers a connected living room and dining room (divided by a fireplace) that extends the full depth of the house. Also on the ground floor are a family room, powder room, and the kitchen. The family room is open above, rising to a vaulted ceiling nearly two storeys high.

Upstairs, there are three bedrooms and a bathroom with entrances from both the master bedroom and the main hall. One of the bedrooms opens onto the two-storey space above the family room; shutters provide privacy when it is required.

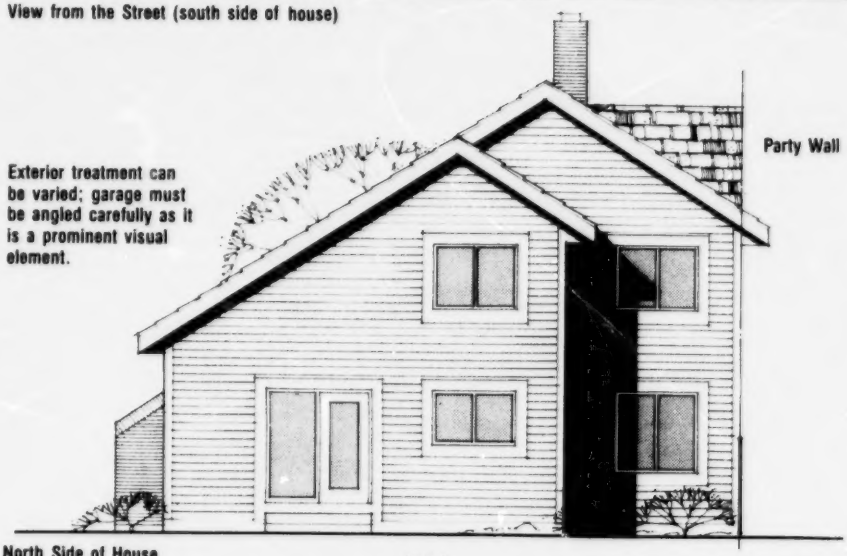
At a landing a few steps down from the second floor, a door opens onto a sun deck on the roof of the garage. Light from the deck passing through the door will fall into the family room for part of the day.

Solar Features

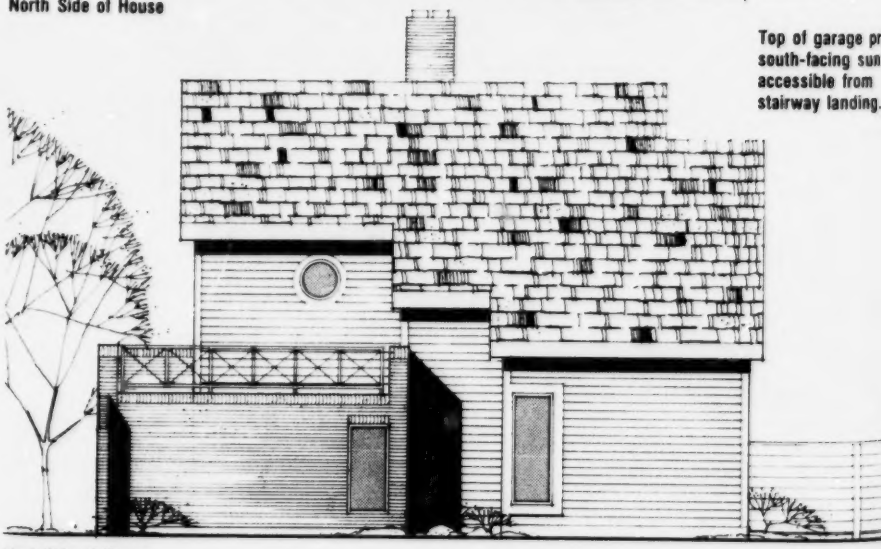
The south-facing glass in this design can be expected to provide over 25% of the house's heating requirements (depending on location). There are limits, however, on solar access to many of the rooms in the house, since the narrow lot size means that the garage must be placed on the south face of the house, thus leaving a relatively narrow south face. This is partially overcome by the interconnection between the living and dining areas, and by the way light is allowed to enter the family room via the sun deck.

Natural air circulation is aided by the two-storey space over the family room; however, additional distribution of solar gain by means of a forced air system is advisable.

View from the Street (south side of house)



North Side of House

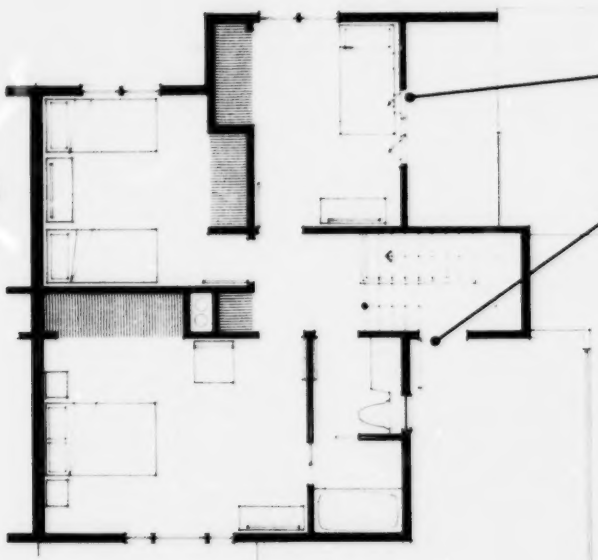


Street

East Side of House

SEMI-DETACHED HOUSES

SECOND FLOOR



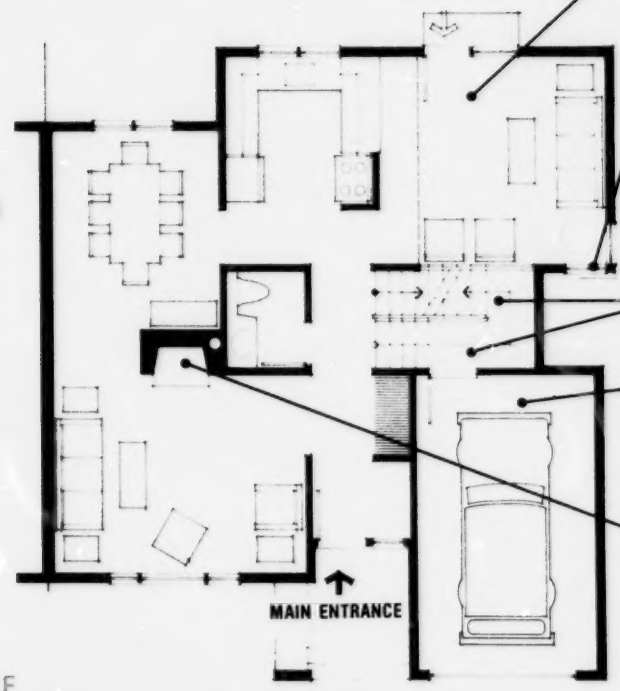
Bedroom overlooks family room below with shutters available for privacy.

South-facing sun deck accessible from landing on staircase.

Family room is open above.

Corner window will provide direct sunlight to the rear of the house during part of each day (early morning in the unit shown).

GROUND FLOOR



Stairs and informal areas are concentrated in one part of the house, allowing their use without disturbance to the dining or living rooms.

Open stairway admits light from the sun deck to the family room.

Garage could be turned into a double garage if lot size permits; this would make room for a larger deck and make the house seem larger from the street.

Fireplace should be provided with outside combustion air supply.

S

PERFORMANCE

Vancouver	**35.4**	**28.0**	**5.0**
Ottawa	52.2	27.5	6.8
Regina	65.3	27.2	6.7

A forced-air system is used to avoid overheating.

0 1 2 3 4

METRES

DESIGN SIXTEEN

About this Design

This semi-detached house is designed to be built on the south side of an east-west street, so that the rear of the house faces south. Each unit provides 154 m² of floor space in a two-storey split-level design. In addition, there is a partial basement and a crawl space. The house is designed to fit on a lot as narrow as 20 metres.

The main entrance to the house is on the upper portion of the ground floor, which also contains the kitchen and dining areas. The lower level of the ground floor contains a living room, family room and powder room. The living room is open to the dining area on the upper level, separated only by a railing. In addition, part of the dining area is open above in an atrium space that rises past the second floor level to the roof, where there is a skylight.

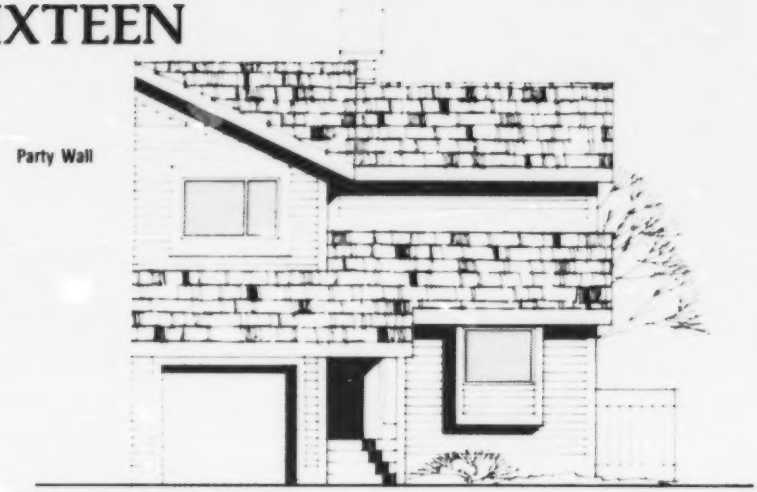
On the second level, two of the rooms open onto the atrium; they can be provided with shutters for privacy as required. In addition, the stairway between floors is open, providing views down into the living room from three sides above.

The upper level of the second floor contains two bedrooms, while the lower level contains the master bedroom. Attached to the master bedroom is a den or "parent retreat."

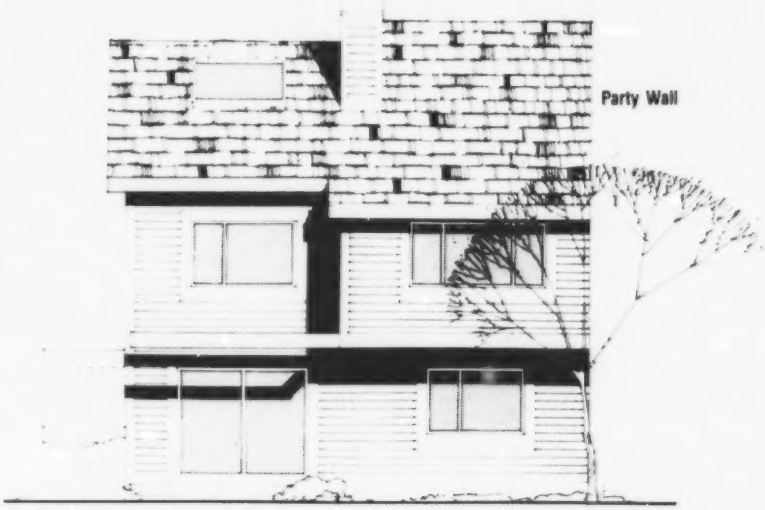
Solar Features

The south-facing glass areas, including the skylight, will provide over 25% of the heating requirements of the house (depending on location). The design allows almost every room in the house direct solar access because of the open layout and the skylight. The open design also provides for good natural circulation of solar heat, which will control the temperature swing and provide a more comfortable indoor environment.

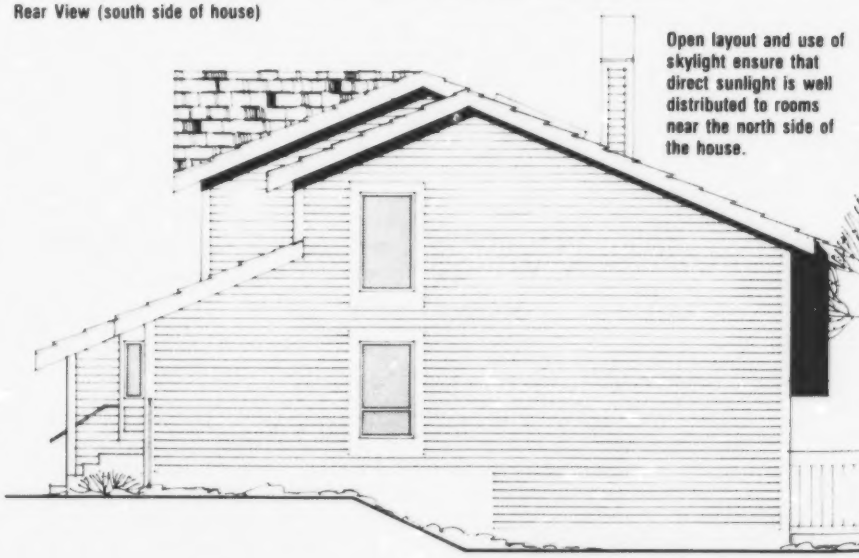
The skylight is likely to allow substantial heat gain during summer months, and heat loss at night during the winter. Blinds designed for use with skylights can overcome these problems.



View from Street (north side of house)



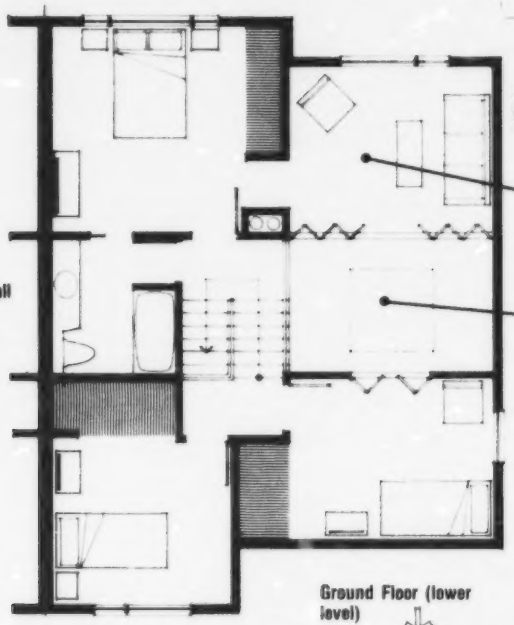
Rear View (south side of house)



Open layout and use of skylight ensure that direct sunlight is well distributed to rooms near the north side of the house.

SEMI-DETACHED HOUSES

SECOND FLOOR



Second Floor (lower level)

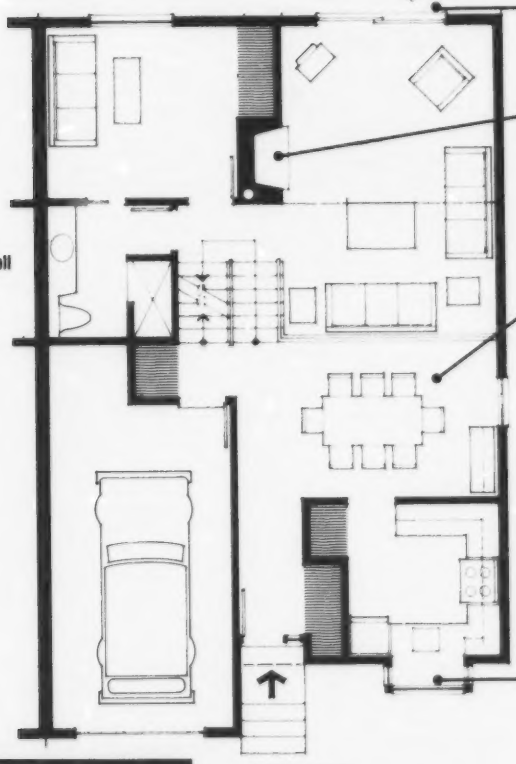
Den off master bedroom could be a fourth bedroom, with minor design changes.

Den, stairway and upper level bedroom overlook the living room.

House is a split-level with a central staircase.

Ground Floor (lower level)

GROUND FLOOR



Patio doors provide solar gain and access to rear yard.

Fireplace in living room should be recirculating type with outside air supply.

Dining area will receive light from skylight and living room.

Projecting window provides visual interest from both inside and outside.

S

PERFORMANCE

Vancouver	**35.2**	**29.8**	**6.3**
Ottawa	58.6	26.2	2.5
Regina	70.6	28.8	1.3

MAIN ENTRANCE

0 1 2 3 4

METRES

DESIGN SEVENTEEN

About this Design

This two-storey semi-detached house is designed to be built on the north side of an east-west street, so that the street side of the house faces south. It is designed for a lot 22 metres wide. It provides 142 m² of floor space, plus a basement. The design as presented does not include a garage.

On the ground floor, there is a spacious living room with fireplace and a large south-facing window. The dining room at the rear opens onto the living room and has direct access to the kitchen, which is large enough to accommodate a breakfast area.

On the second floor, three bedrooms and a main bathroom are provided. The master bedroom features a large walk-in closet and a large south-facing window.

Two different options for the exterior of the house are presented. The first emphasizes the existence of two separate units within the double by repeating the same visual pattern on both sides (in mirror image). The other facade provides a unifying roof over the two units.

Solar Features

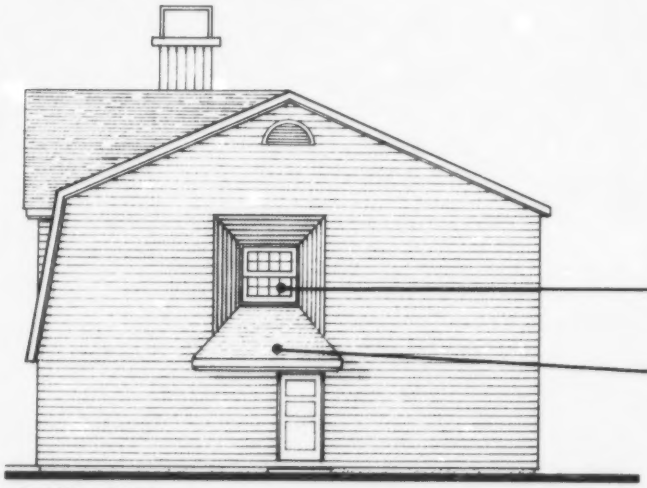
The window area in the house is concentrated on the south side, so that solar gain can provide 25 to 30% of the heating requirements (depending on location). The party wall between the two units has high thermal mass, which provides heat storage.

Distribution of the solar gain is carried out by a thermostatically controlled circulation fan that operates when the temperature in south-facing rooms rises above the set temperature. In addition, the design calls for the use of a heat recovery ventilator, which can also have the effect of improving air circulation around the house.

View from Street (south side of house)

Both halves of semi-detached house are shown.

South Side of House (alternative facade)


Roof detail would change slightly if the alternative facade for the south face of the house were used.
Facade of house can be changed without changing interior design.
Window is recessed into the side of the wall.
Overhang protects side entrance to house.

East Side of House

SEMI-DETACHED HOUSES

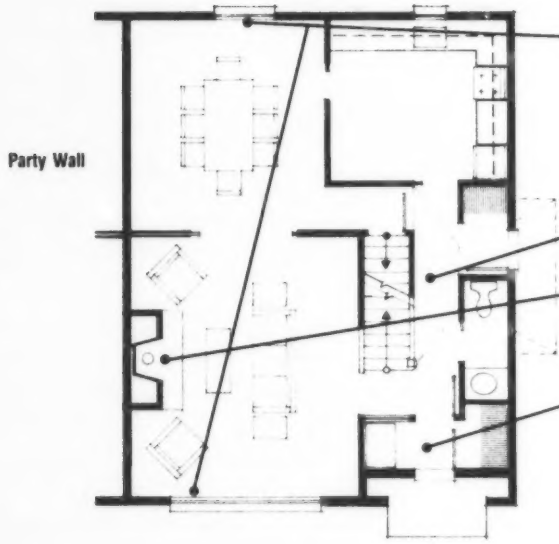
SECOND FLOOR

Recessed window and roof below.

Area between stairway and window is open between the ground floor and second floor.

Floor plan of attached unit is reverse of plan shown here.

GROUND FLOOR



Openable windows are positioned to provide air circulation and cross ventilation during the summer.

Area above hallway is open to the second floor above.

Fireplace should be manufactured type with outside air supply.

Entrance area is recessed to provide shelter. Inside, a built-in bench is provided and an airlock entry is used to reduce heat loss.

S

MAIN ENTRANCE

PERFORMANCE

Vancouver	27.0	27.7	3.9
Ottawa	43.0	29.4	1.2
Regina	51.4	30.6	0
Sudbury	**52.1**	**24.6**	**0.8**

0 1 2 3 4

METRES

DESIGN EIGHTEEN

About this Design

This townhouse is designed to be built on the north side of an east-west street, so that the front of the house faces south. Each unit requires a lot 6 metres wide. Each unit has 134 m^2 of floor space, plus basement.

The house features a split-level design, with living space provided on two (split) floors. The entry area, powder room, and garage are located on a third, lower, level.

From the entry area, the stairs lead up to the lower half of the first floor, which contains the kitchen and dining area. A rear door off the kitchen opens onto the back deck. The upper half of the first floor features a spacious living room with fireplace and with direct access onto a south-facing balcony.

All three bedrooms and the main bathroom are on the second floor, split between the upper and lower levels.

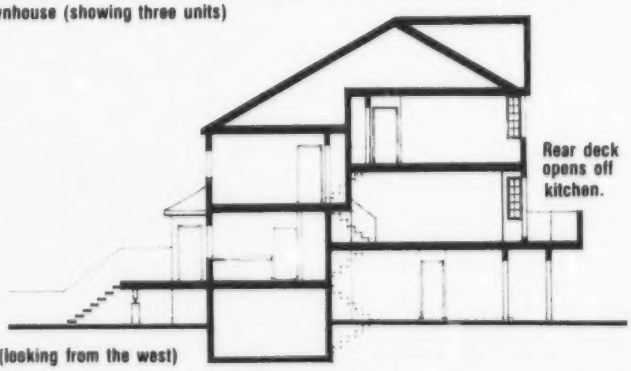
Solar Features

In spite of the narrow width of each townhouse unit, the design provides sufficient south-facing glass area to allow solar gain to supply nearly 30% of the house's heating requirements (depending on location).

The relatively large size of the south-facing rooms means that a reasonable proportion of the house receives direct solar gain; the depth of the house, however, ensures that several rooms do not. A circulation fan is therefore provided to draw solar heat from the south-facing rooms when temperatures rise above a preset level. The design allows the heat to be circulated to the basement, where the mass in the concrete walls and floor provides heat storage. In addition, the house has a heat-recovery ventilator, which boosts the circulation of air through the unit. Further storage is provided by the concrete walls between each townhouse unit.

View from Street (showing three units, south side of townhouse)

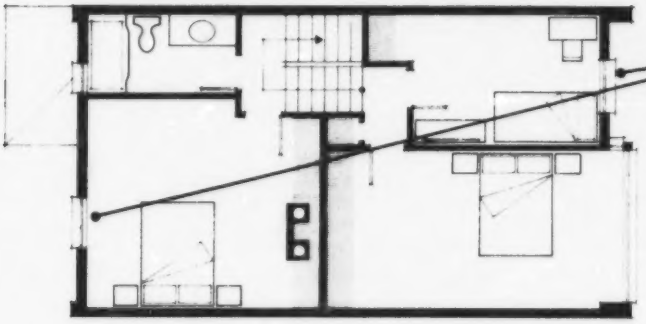
North Side of Townhouse (showing three units)



Section of House (looking from the west)

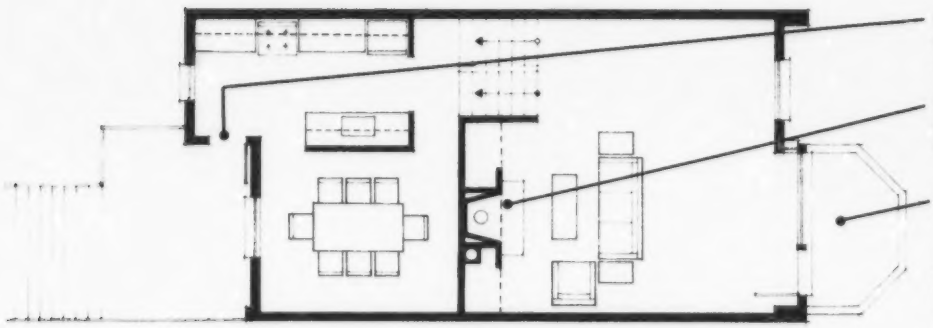
T O W N H O U S E S

SECOND FLOOR



Location of openable window is designed to provide cross ventilation during the summer.

FIRST FLOOR



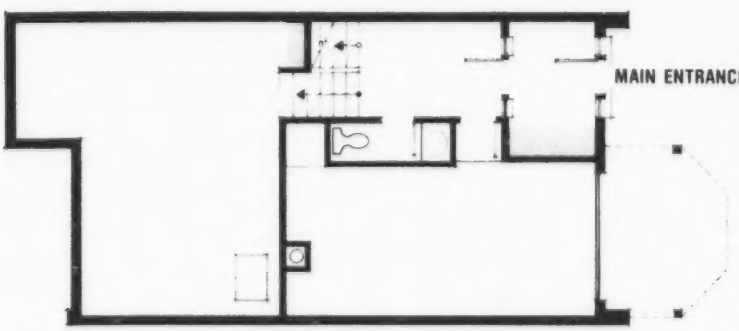
Access to rear door and deck via the kitchen area.

Fireplace should be premanufactured type with outside air supply.

Balcony off living room overlooks street.

Room size is maximized by keeping area given over to hallways to a minimum.

BASEMENT



MAIN ENTRANCE

Front entrance includes an airlock entry to reduce heat loss.

Note: Floor plan shown is for a single unit only. East and west walls are party walls, shared with adjacent units.

S

PERFORMANCE

Vancouver	21.9	32.2	10.7*
Ottawa	38.6	28.8	6.8
Regina	48.9	28.8	5.1
Sudbury	**45.7**	**28.9**	**2.1**

* Overheating must be avoided

0 1 2 3 4

METRES

DESIGN NINETEEN

About this Design

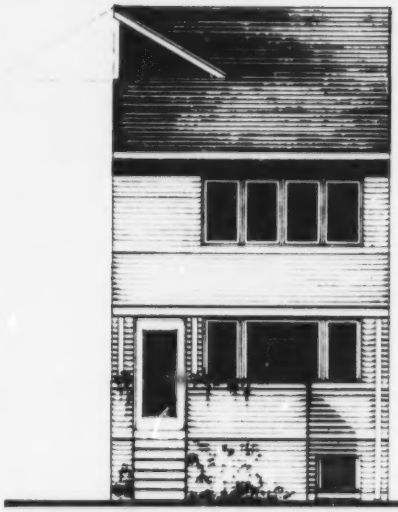
This townhouse is designed for the south side of an east-west street, so that the rear of the house faces south. It can be built on a lot 5 metres wide.

The house is a split-level providing 104 m² of floor space, excluding the basement and garage. The living areas of the house are on two floors, each divided into a lower and an upper level. Downstairs from the first floor is a two-level basement-garage area, which also serves as the utility entrance to the house and provides space for a small powder room.

Many townhouse split-level designs provide the main entrance to the house at the garage level. This design, on the other hand, locates the main entrance on the upper level of the first floor, providing increased convenience, reduced stair traffic, and less sense of stratification of the home (which some buyers find undesirable).

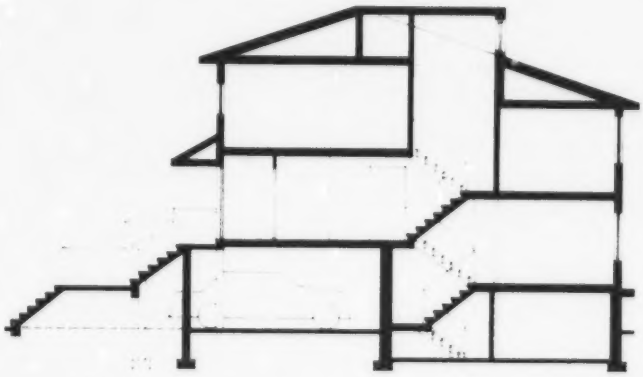
The first floor entry area connects directly to the dining room and the kitchen. The lower level of the first floor is entirely occupied by the living room, which opens onto a rear raised deck.

The second floor includes three bedrooms and the main bathroom, with one bedroom on the lower level and the rest on the upper. The stairwell is built in an open design from the basement to the upper level of the second floor and beyond, rising to a clerestory window above the second floor ceiling level.



South Side of House (showing single unit only)

View from the Street (north side of hous



Rear deck has solid banister.

Section of House (looking from the west)

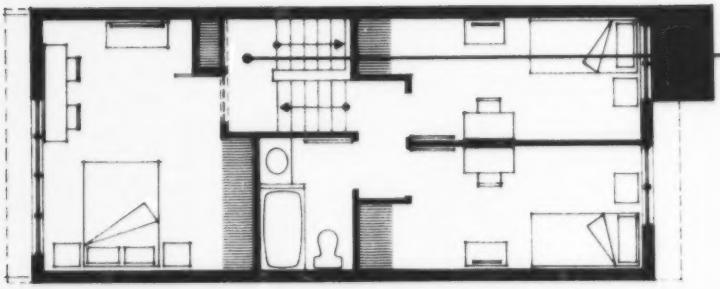
Solar Features

In spite of the narrow south-facing side of the house, the design provides sufficient glass area to ensure that 25 to 30% of the building's heating requirements can be provided by solar gain. This significant solar contribution is partially explained by the fact that this house, like most townhouses, has fairly low heating requirements. Nevertheless, the large glass areas in the living room, bedroom, and the south-facing clerestory generate considerable solar gain.

The open stairwell will help the natural circulation of solar gain, but additional circulation will be necessary to prevent overheating. The party walls between the units will also help prevent overheating, as they provide thermal mass areas for storage of excess solar gain.

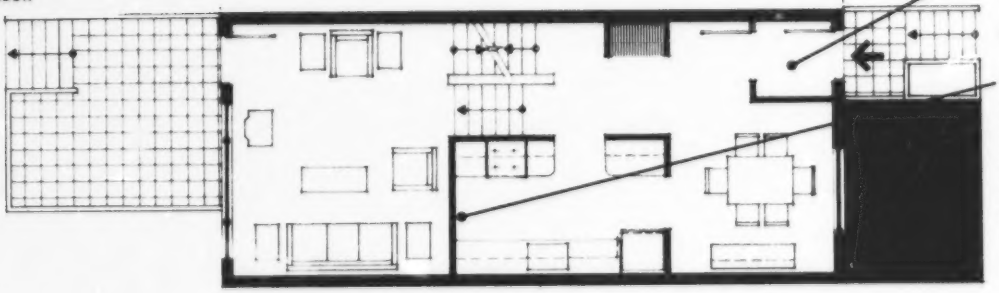
T O W N H O U S E S

SECOND FLOOR



Stairwell receives direct sunlight from clerestory window above.

FIRST FLOOR

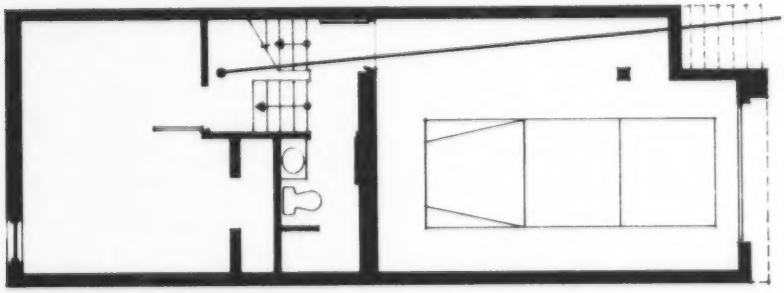


Airlock entry reduces heat loss at front door.

MAIN ENTRANCE

An opening in the solid kitchen wall could be provided to allow views into the living room, increased sunlight to the kitchen, and improved air circulation.

BASEMENT



Utility entrance provides direct access from the garage to the living areas of the house.

S

PERFORMANCE

Vancouver	15.0	35.2	10.1*
Ottawa	31.6	27.7	6.0
Regina	40.5	27.1	4.3
Toronto	**26.6**	**30.1**	**6.5**

* Overheating must be avoided.

0 1 2 3 4

METRES

DESIGN TWENTY

About this Design

This two-storey townhouse was designed to be built on the north side of an east-west street, so that the front of the house faces south. Each individual unit requires a lot 4.3 metres wide.

The design provides 110 m² of floor space on the two main levels, plus a basement. The design also provides for a sunken garage, the back of which extends into the basement space and the front of which protrudes towards the street. The roof of this extended garage serves as support for a deck opening off the kitchen on the first floor of the house.

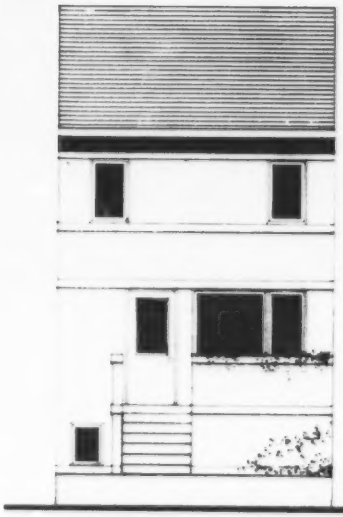
The kitchen, living room and dining room are located on the first floor. The layout is open, with few dividing walls. A door opens off the living room to the rear yard and deck.

On the second floor there are three bedrooms and a bathroom. In addition, a central portion of the second floor is open, looking down onto the dining room and up to a skylight on the roof above.

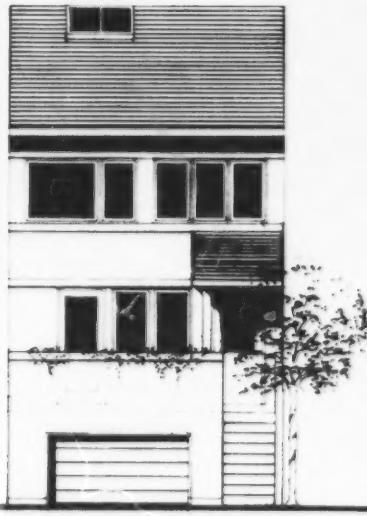
Solar Features

Although the south-facing side of the house is small in area, the design provides a considerable area of south-facing glass. This feature, coupled with the relatively low heating requirements of most townhouses, allows the sun to provide about 25% of the house's heating requirements (depending on location). In addition, the house design allows sunlight and solar heat to reach deep into the house structure. Specifically, the open layout of the ground floor and the open space rising above the dining room to the skylight are both beneficial.

As in most townhouses, the mass in the party wall between units helps to provide storage of solar gain.



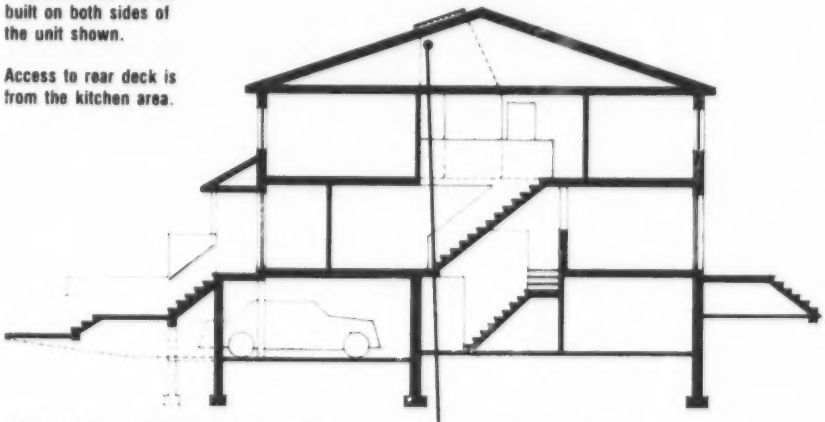
North Side of House (showing single unit only)



View from the Street (south side of house)

Attached units can be built on both sides of the unit shown.

Access to rear deck is from the kitchen area.



Section of House (looking from the east)

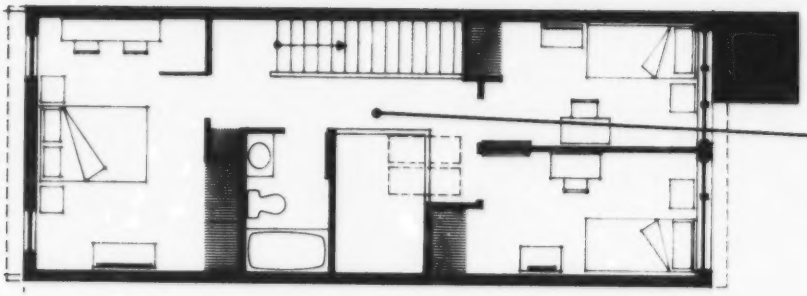
Skylight provides direct sunlight to hallway and open space below.

Ground floor layout is open from front to rear.

During the summer, the design should allow for good cross ventilation. The skylight may, however, provide excessive solar gain, if it is not provided with blinds or other shading devices.

T O W N H O U S E S

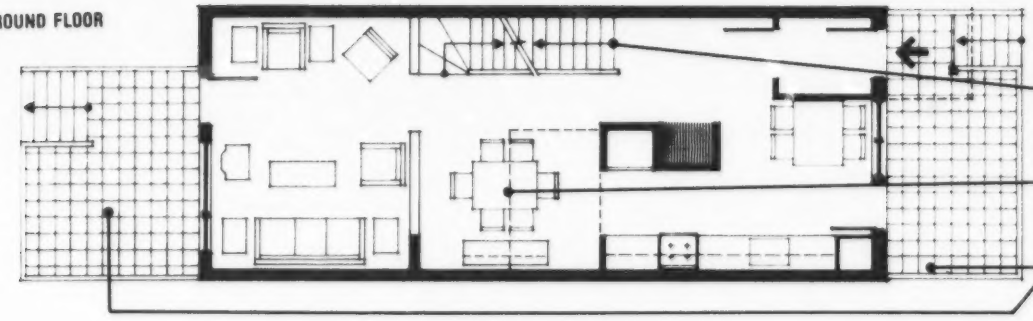
FIRST FLOOR



Skylights above will require summertime shading.

Hallway overlooks dining room below.

GROUND FLOOR



MAIN ENTRANCE

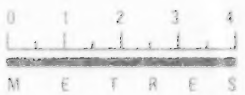
Stairway provides access to basement and garage.

Area above dining room is open to the skylight above the second floor.

House has decks front and rear.

PERFORMANCE

Vancouver	15.4	32.2	5.5
Ottawa	32.2	24.8	1.9
Regina	41.6	23.8	1.3
Toronto	**27.4**	**26.3**	**3.1**



DESIGN TWENTY-ONE

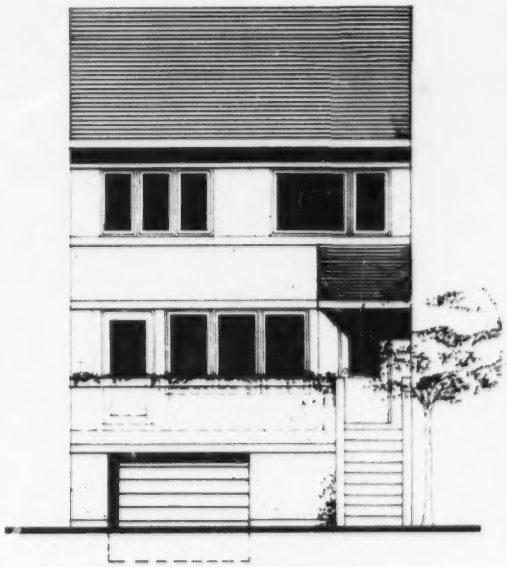
About this Design

This two-storey townhouse is designed to be built on the north side of an east-west street, so that the street side faces south. Each unit requires a lot 6 metres wide. Each provides 116 m² of floor area, plus basement.

As with Design 20, this house provides for a sunken garage, with the rear portion extending into the house basement and the front portion extending towards the street. The roof of this garage extension gives support for a deck that opens off the first-floor living room.

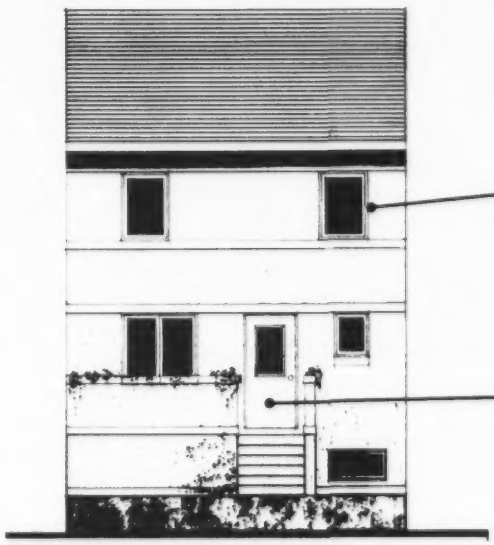
In addition to the living room and entry way, the first floor contains dining room, kitchen, and powder room. The floor plan is fairly open, with easy connection between individual spaces. In addition, there is a large "pass-through" opening in the wall separating the kitchen from the living room, and a partial-height wall separating the living room from the entry area. A doorway at the rear of the ground floor opens onto a rear deck.

There are three bedrooms and a bathroom on the second floor.



Attached units can be built on both sides of the unit shown.

View from the Street (south side of house)



Window area on north side of house is limited, while still providing a sufficient area of openable window to ensure summertime cross ventilation and natural lighting to rooms at rear.

Access to rear deck is from the kitchen area.

North Side of House (single unit only)

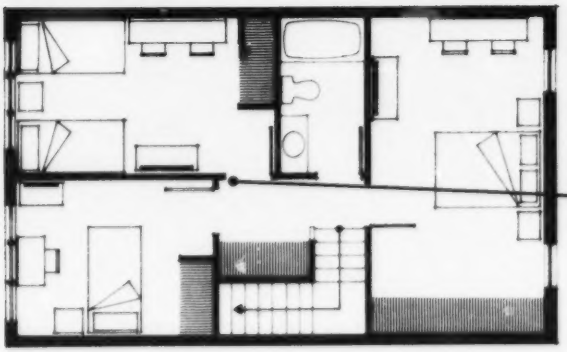
Solar Features

The south-facing glass area on this townhouse provides approixmately 25 to 30% of the house's heating requirements (depending on location), in spite of the relatively small south-facing wall available. The open design of the ground floor allows the sun to reach deep into the interior of the house; for instance, the pass-through opening admits direct light to the kitchen area. At the same time, the open design should permit good cross flow ventilation during the summer.

As with many modern townhouses, the concrete used in the construction of the party walls between units, if exposed, can provide some storage of solar heat, helping to control overheating. This storage might be particularly beneficial on the second floor, where the depth of the house and the privacy requirements of bedrooms limit the distribution of solar gain by natural convection. As with all houses, additional circulation of the solar gain by fans or other mechanical systems is beneficial.

T O W N H O U S E S

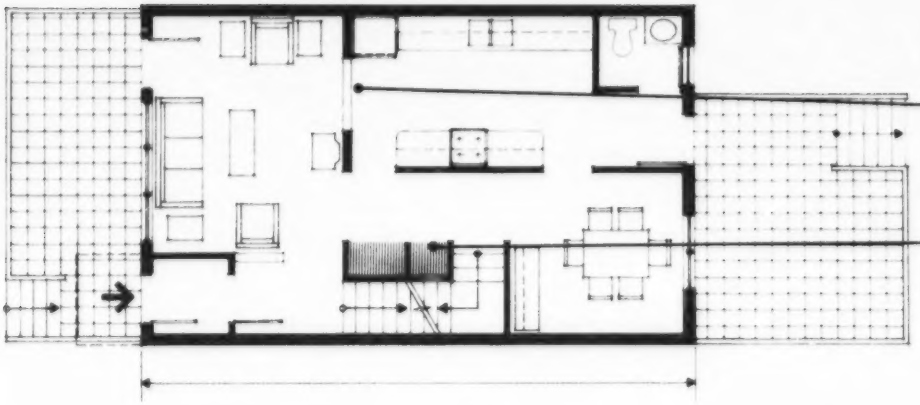
SECOND FLOOR



Note: Floor plan shown is for a single unit only. East and west walls are party walls, shared with adjacent units.

Elimination of the partition would provide for a single large south-facing bedroom, with space for ensuite bathroom.

GROUND FLOOR



MAIN ENTRANCE

Pass-through opening assists in natural air circulation on the ground floor and admits sunlight to the kitchen area.

Stairway provides access to basement and to garage.

S

PERFORMANCE

Vancouver	14.9	32.0	6.3
Ottawa	30.8	25.3	3.8
Regina	38.9	25.1	2.0
Toronto	**25.7**	**27.3**	**4.0**

0 1 2 3 4

M E T R E S

DESIGN TWENTY-TWO

About this Design

This two-storey townhouse is designed for the south side of an east-west street, so that the rear of the house faces south. The design requires a lot 6 metres wide, and provides a floor area of 119 m², plus basement. The design as presented does not include a garage.

The house features a split entry, which allows the main entrance to be at ground level. The first floor living area, five steps up from the entry hall, includes a kitchen with a breakfast area, a powder room, and a large L-shaped living room-dining room combination. The living room portion of this space faces south, and has a doorway onto the rear deck of the house.

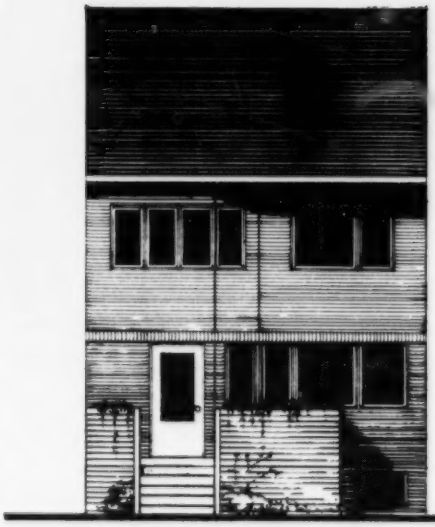
There are three bedrooms and a bathroom on the second floor. Two of the bedrooms are on the south side, where they receive a considerable amount of direct sunlight.

Solar Features

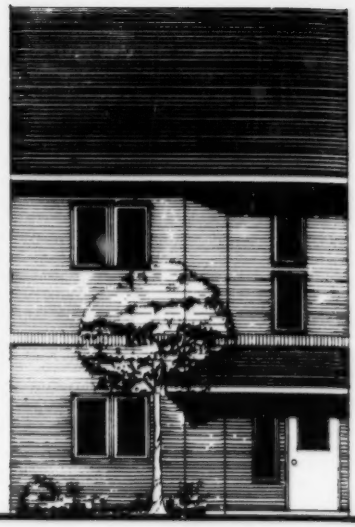
The south-facing glass area and the relatively low heating costs of a well-insulated townhouse allow solar energy to provide 25 to 30% of the heating requirements of this house. The large south-facing room on the ground floor and the open connection to the stairway and the kitchen on the north side of the house allow for natural circulation of this solar gain.

On the second floor, circulation is more restricted. A mechanical system such as a two-speed fan on the forced air furnace would help prevent the possibility of overheating.

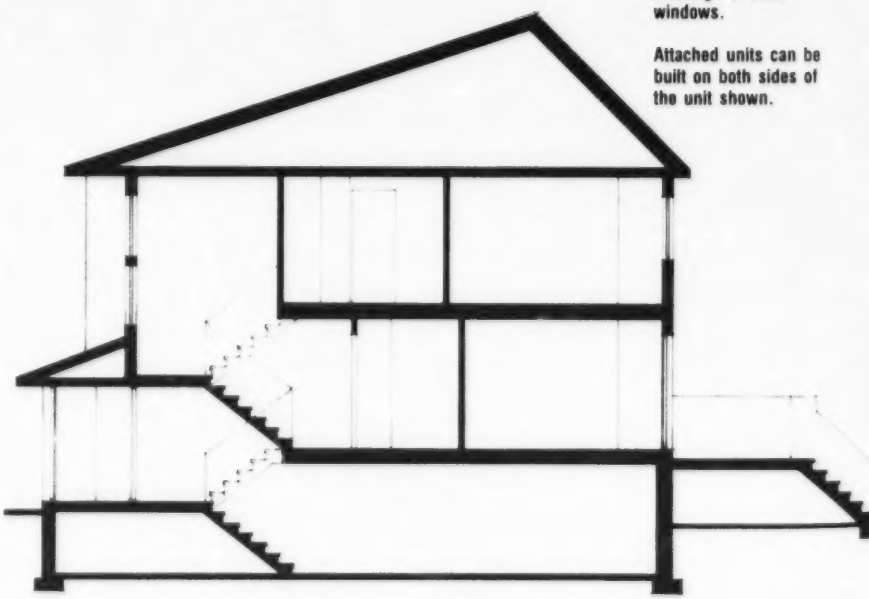
The angled window in the bedroom on the south-west side of the unit will provide most of its solar gain in the morning when the house is heating up from a cold night. Other units in the row — those with the reverse floor plan — will, however, receive this extra solar gain in the afternoon, typically at the time when the house does not need more solar input.



South Side of House (single unit only)



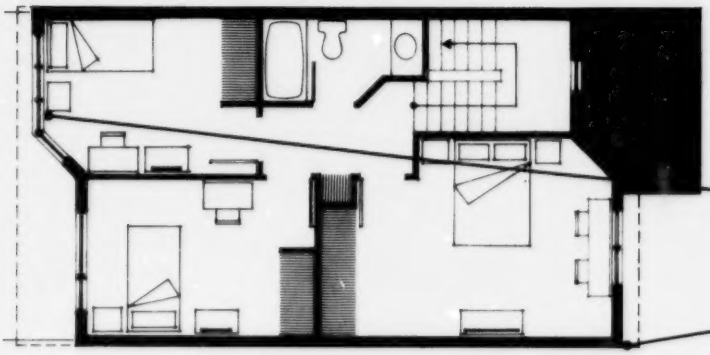
View from the Street (north side of house)



Section of House (looking from the east)

T O W N H O U S E S

SECOND FLOOR

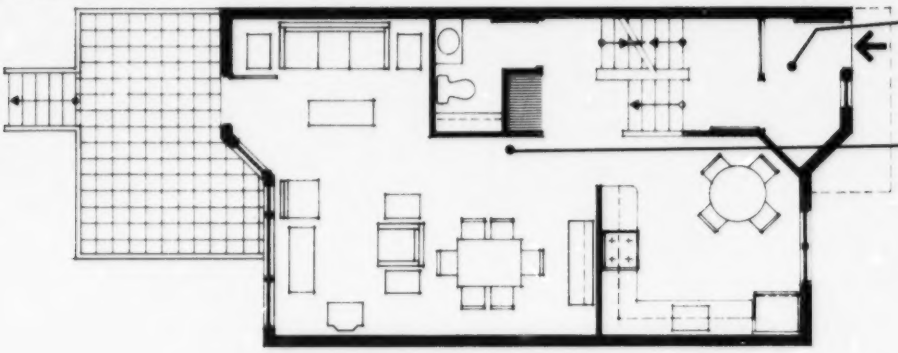


Dotted line shows the extent of the south-facing roof overhang, which provides summertime shading to some of the windows.

Window faces south-east, providing extra early morning solar gain.

Walls between units are generally concrete, and so can provide thermal mass for storage of solar gain.

GROUND FLOOR



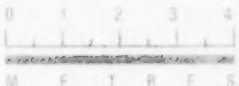
Entry area includes an air lock to reduce heat loss.

Large room helps in the distribution of solar gain.

Note: Floor plan shown is for a single unit only. East and west walls are party walls, shared with adjacent units.

PERFORMANCE

Vancouver	15.5	35.9	8.0*
Ottawa	31.6	29.3	3.9
Regina	40.3	28.7	2.3
Toronto	**27.0**	**27.0**	**5.0**



DESIGN TWENTY-THREE

About this Design

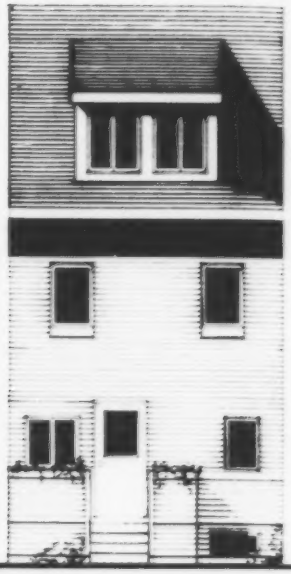
This three-storey townhouse is designed for the north side of an east-west street, so that the front of the house faces south. Each unit requires a lot 4.25 metres wide. The house provides 118 m² of floor area, plus a full basement. As presented, the design does not include a garage.

This house offers several unusual features. The ground floor is the largest floor, extends forward from the front of the second and third storeys. The design features a deep living room-dining room combination, served by a large area of south-facing window. An irregularly shaped space above the dining room is open through both floors above, rising to a ceiling at the top of the house some five metres above eye level. At the rear of the ground floor there is a powder room, a kitchen and a breakfast nook that opens onto a rear deck.

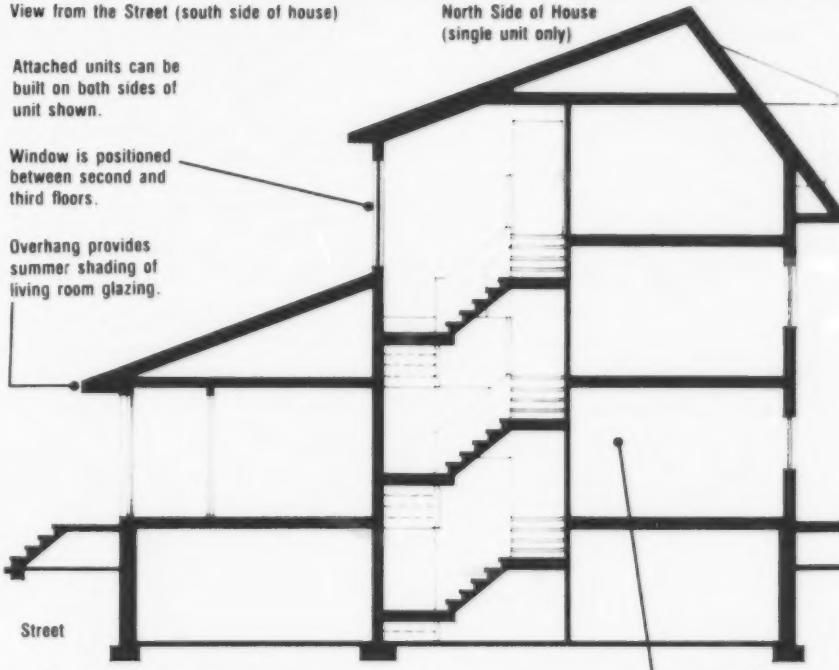
The second floor features a single large bedroom in the rear, and the main bathroom. The hallway of the second floor overlooks the dining room below.

The third floor includes two bedrooms, both of which are provided with dormered windows on the north side. In addition, the third floor includes a large open area overlooking the second floor below (and, via the smaller open area in the second floor, overlooking the ground floor dining room area).

View from the Street (south side of house)



North Side of House (single unit only)


Attached units can be built on both sides of unit shown.
Window is positioned between second and third floors.
Overhang provides summer shading of living room glazing.
Street
Sun space rises two floors above dining room.
Bathroom ceiling slanted and glassed, in order to receive direct sunlight.

Section of House

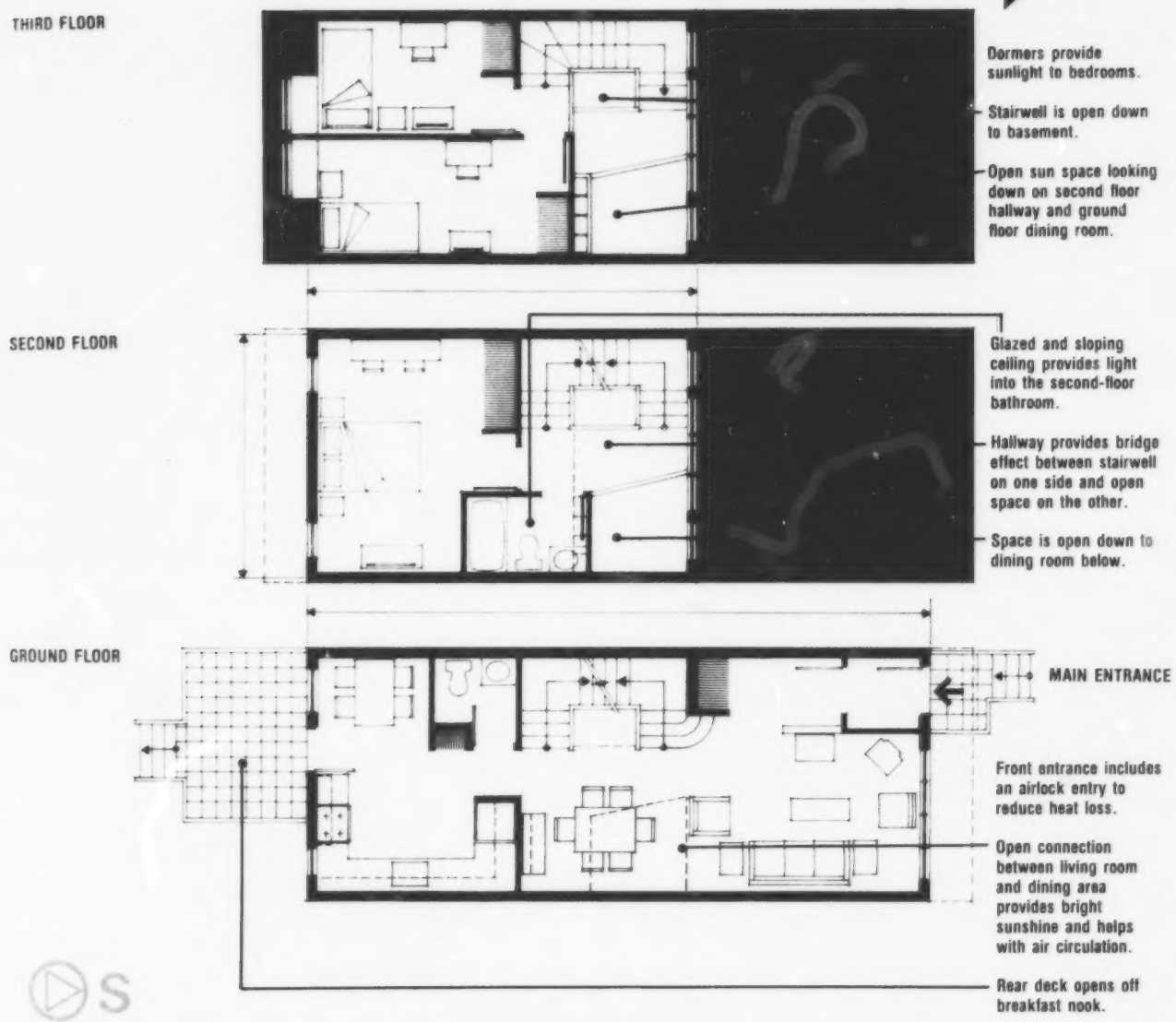
Solar Features

The south-facing glass on this townhouse can provide approximately 35% of the heating requirements. The glass is arranged mainly in two large groupings. The first glass area is in the living room, where it can provide light and solar gain deep into the house.

The second large block of glass is located on the south-facing wall adjacent to the open space between the second and third floors. The windows extend virtually the full width of the building and are nearly a storey in height. Thus these windows provide direct light and solar gain to the stairway, to the hallways on the second and third floors, and to the dining area in the middle of the ground floor.

Apart from allowing sunshine to reach many parts of the house, the open design encourages natural air circulation around the house. Additional circulation by means of the furnace fan will be beneficial in preventing overheating.

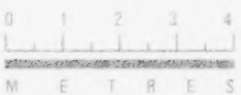
T O W N H O U S E S


THIRD FLOOR
Dormers provide sunlight to bedrooms.
Stairwell is open down to basement.
Open sun space looking down on second floor hallway and ground floor dining room.
SECOND FLOOR
Glazed and sloping ceiling provides light into the second-floor bathroom.
Hallway provides bridge effect between stairwell on one side and open space on the other.
Space is open down to dining room below.
GROUND FLOOR
MAIN ENTRANCE
Front entrance includes an airlock entry to reduce heat loss.
Open connection between living room and dining area provides bright sunshine and helps with air circulation.
Rear deck opens off breakfast nook.

Note: Floor plan shown is for a single unit only. East and west walls are party walls, shared with adjacent units.

PERFORMANCE

Vancouver	12.8	40.6	7.1
Ottawa	29.4	34.4	3.6
Regina	37.0	34.2	2.5
Toronto	**24.4**	**37.3**	**5.5**



DESIGN TWENTY-FOUR

About this Design

This townhouse is designed to be built on the south side of an east-west street, so that the rear of the house faces to the south. Each unit requires a lot 6 metres wide.

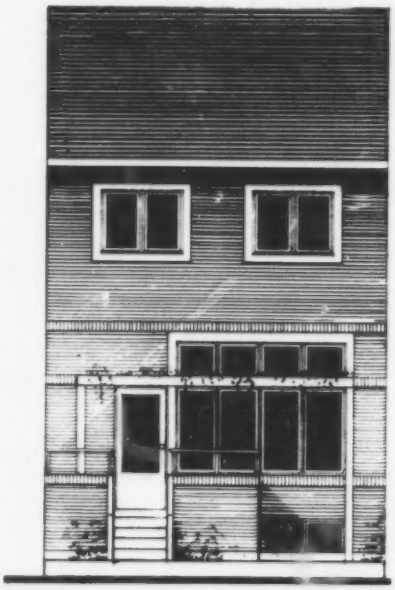
The house is designed as a partial split level, providing 119 m² of floor area on the two principal floors. Downstairs from the first floor is the basement-garage area, which also includes the main entrance to the house.

The second floor of the house provides three bedrooms and the main bathroom, all on the one level. The first floor, however, is on two levels, with the upper level including kitchen, breakfast area, and dining room. The dining room overlooks the lower level of the first floor, which is entirely occupied by the living room. The five steps down to the lower level create a sunken living room effect. The living room also features large south-facing windows, a deck at the rear, and a high ceiling.

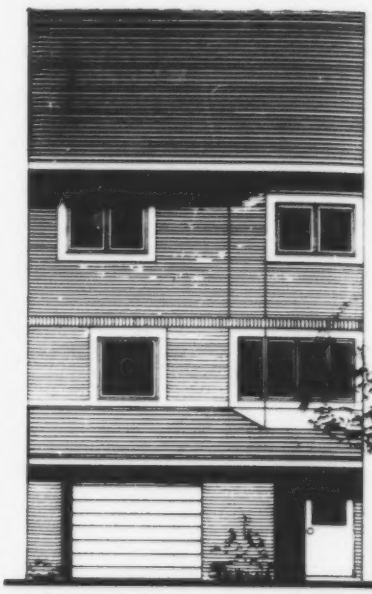
Solar Features

The glass area on the south of the townhouse is sufficient to provide approximately 30% of the house's heating requirements, depending on location. The bulk of the window area is in the living room. Because of the open connection between the living and dining rooms, the ground floor interior and stairwell also receive direct sunlight.

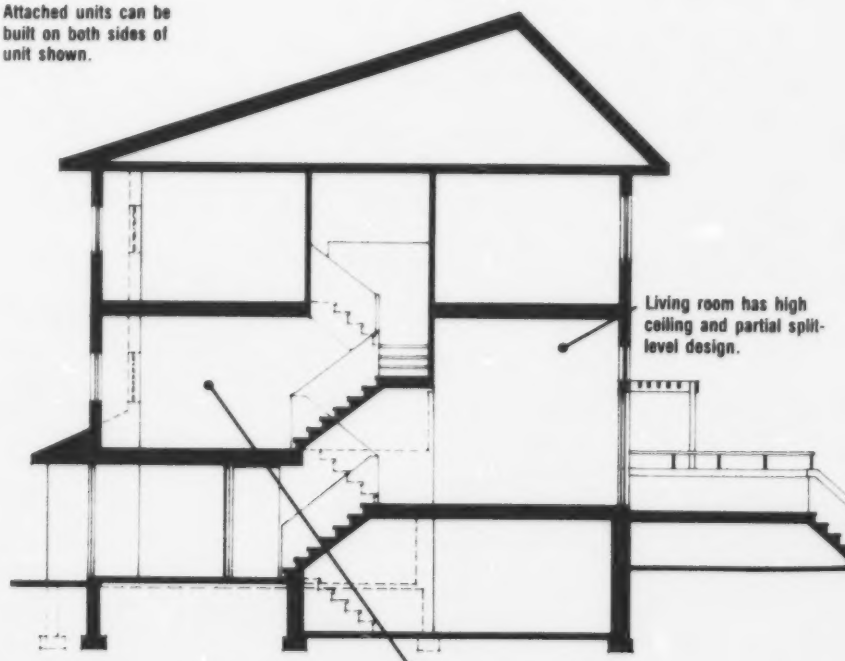
The design of the upstairs bedrooms does not permit good natural circulation of solar gain. Mechanical circulation is required to help control overheating. In addition, the mass in the party walls dividing one unit from the next provides some storage of any excess solar heat gain.



South Side of House (single unit only)



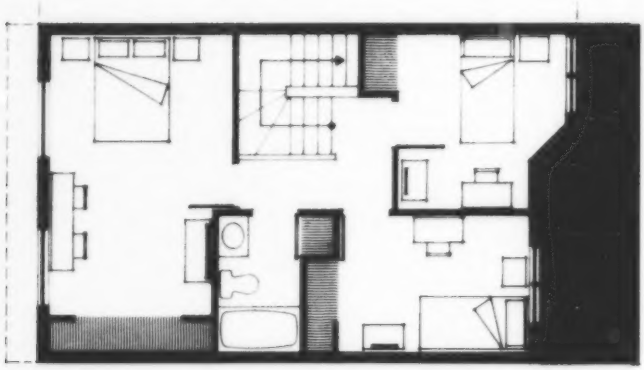
View from the Street (north side of house)


Attached units can be built on both sides of unit shown.
Living room has high ceiling and partial split-level design.
Dining room overlooks sunken living room.

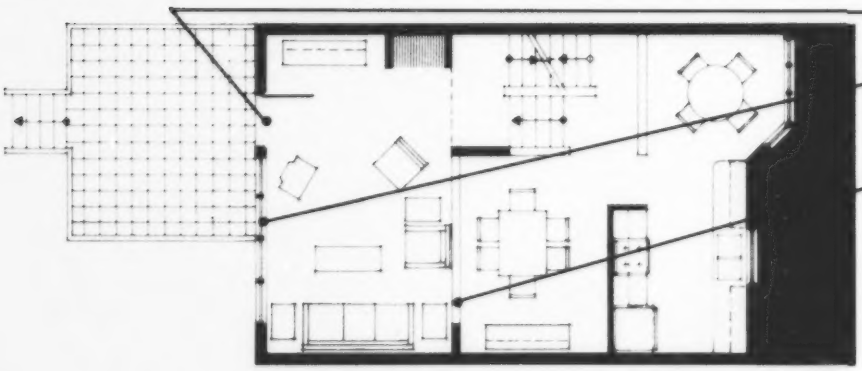
Section of House (looking from the west)

T O W N H O U S E S

SECOND FLOOR



FIRST FLOOR



Deck opens off living room.

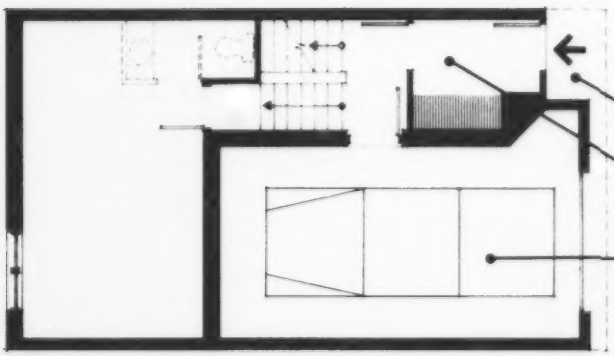
Windows into living room are tall, for maximum solar gain.

Knee-wall separates dining room from sunken living room.

Lower Level

Upper Level

BASEMENT



MAIN ENTRANCE

Shelter is provided over main entrance.

Air lock entry way can reduce discomfort caused by drafts.

Garage is at street level.

Note: Floor plan shown is for single unit only. East and west walls are party walls shared with adjacent units.

PERFORMANCE

Vancouver	15.3	38.8	8.9*
Ottawa	31.4	31.4	5.0
Regina	39.4	30.7	4.0
Toronto	**26.3**	**33.7**	**6.1**

* Overheating must be avoided.

0 1 2 3 4

METRES

Further Reading

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Moisture and Air, Problems and Remedies. NHA 5968. Ottawa: Canada Mortgage and Housing Corporation, 1989.

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Measures for Energy Conservation in New Buildings 1983. NRCC No. 22432. Ottawa: National Research Council of Canada, 1983.

R-2000 Builders' Manual. Ottawa: Canadian Home Builders' Association, 1987 edition.

Other Resources

Audio-Visual Presentation: Energy Efficient Housing Construction. Ottawa: Canada Mortgage and Housing Corporation, 1982.

Computer Software: ENERPASS. Available from Enermodal Engineering Ltd., 421 King Street North, Waterloo, Ontario N2J 4E4.

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